Weeds

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JOURNAL OF THE ASSOCIATION OF REGIONAL WEED CONTROL CONFERENCES.

VOLUME I JULY 1952 NUMBER 4

The Present Status of the Halogeton Problem[1]

C. ERICKSON,[2] H. L. MORTON,[2] E. W. TISDALE,[3]
and GEO. ZAPPETTINI[3]

CONSIDERABLE concern and confusion exists regarding the problem presented by the present occurrence and potential spread of halogeton *(Halogeton glomeratus)* (M. Beib) (C. A. May) in the United States. It is now 18 years since this weed was first found near Wells, Nevada (10). Since that time the plant has been reported from a broad region extending from Lassen county, California (2) to the southern edge of Montana (20).

The native home of *Halogeton glomeratus* is in the Kirghiz steppes of southwestern Siberia, eastward to the deserts of Sungaria in northwestern China (Fig. 1). Here it is reported to occur in fair abundance on dry saline clay spots. The area annually produces several million head of livestock, including sheep, goats, cattle, and horses. No information is available at this time on the relation of halogeton to grazing use and livestock production in this region.

No one knows how halogeton was transported to the United States. One conjecture is that it entered as an impurity in crop seed (3, 5). Other possibilities appear equally probable. Large quantities of wool, including karakul, cashmere, and mohair, are produced in the native home of halogeton. Importations of Karakul and Angora breeding stocks are recorded from 1908 to 1925 (19). Furthermore, an average of 151 million pounds of raw wool has been imported from all foreign sources each year from 1910 to 1940. Since new infestations within the western United States appear to correspond to sheep movements, it seems quite possible that halogeton may have entered the country via wool, pelts, or live animals. It is also possible that this introduction occurred some years before the discovery and identification of the plant.

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FIG. 1. The native home of *Halogeton glomeratus*.

When halogeton was first found in Elko county, Nevada, it was considered as "a fair forage for livestock," and also as a desirable plant along roadsides because of its fire-resisting qualities (5). Apparently it was not known to be poisonous until 1942 when 160 head of sheep died near Wells, Nevada (4). The stomach contents of these animals were found to be composed almost exclusively of halogeton. Numerous announcements of losses of both sheep and cattle followed this initial poisoning report (10).

A wider recognition of halogeton as a poisonous range plant began when about 1500 sheep were poisoned one day in November, 1945 near Bridge, Idaho. News of this loss marked the beginning of a widespread public interest in the weed, culminating in reports such as those in *Life* magazine five years later. This publicity brought the toxicity and distribution of this plant to the attention of the public and indirectly focused national attention upon the underlying problems of overgrazing and range use. Furthermore, the publicity

FIG. 2. A halogeton infestation in the Raft River Valley, Cassia county, Idaho.

created great concern regarding the ecological adaptation, potential spread, and methods of control for this new poisonous weed.

The first attempts at chemical control of halogeton were made by the Nevada State Department of Agriculture in 1943, using contact oil sprays and soil sterilants. This work demonstrated that 1 gallon of diesel oil, 4 pounds of sodium chlorate, and 8 pounds of borax per square rod were effective in killing the annual growth but none gave permanent sterilization against halogeton (5).

The problem in halogeton control is not only to destroy the plant, but to provide conditions favorable for revegetation by desirable native or introduced forage species. The advent of 2,4–D provided a selective herbicide which might make selective control possible. Work with these compounds was begun on a limited scale in both Idaho and Nevada as early as 1945. It soon became evident that halogeton does not respond to small dosages such as are effective in the control of most other annual weeds. Other problems arose in connection with preliminary trials involving competitive control of halogeton by reseeding perennial grasses such as crested wheatgrass *(Agropyron cristatum)*. On some halogeton infested sites, grasses either failed to emerge or if the seedlings did appear, they competed rather poorly with vigorous stands of the weed. On many of the infested areas the natural plant cover is composed mainly of shrubs rather than grasses. The annual precipitation is low and the salt

content of the soil is frequently high, varying widely within short distances. Thus the dominant species change quickly, depending upon soil type. Under these circumstances there was considerable question as to the possibility of uniform establishment of perennial grasses. These preliminary observations and tests together with the continued spread of halogeton indicated the need for more comprehensive and detailed studies.

In 1950 a co-operative project was initiated between the Agricultural and the Forest, Wildlife, and Range Experiment Stations of the University of Idaho to study "The Ecology and Control of Halogeton and other Range Weeds." Several phases of the investigation are now in progress, including studies on plant and seed characteristics; growth habits and longevity; chemical composition; competitive ability; response to selective and non-selective herbicides; adaptation to soil types and salt tolerance; and the relation of the infestations to past and present land use. The mode and place of natural and artificial revegetation by desirable forage species for halogeton control are also being studied. Certain segments of these studies have already been presented (8, 11, 12, 15, and 21), and more will be published soon (13, 22). Results to date indicate that selective herbicides are useful for control of small areas, while over major areas control by both natural and artificial revegetation is giving encouraging results on most sites. The most effective selective chemicals have been the newer heavy esters of 2,4–D and 2,4,5–T. Applications at 2 pounds per acre of acid equivalent applied from June 15 to July 15 have proved most satisfactory. Other 2,4–D formulations should be fortified with 2 gallons of diesel or stove oil per acre.

Halogeton is a member of the *Chenopodiaceae* family. Some of the other members of this family, particularly the Russian thistle, are often mistaken for it. Actually, the plants are distinctly different if they are examined closely. In the vegetative stage the leaves of Russian thistle are thin, elongated and spiny, while those of halogeton are relatively short and plump and bear a fine whitish hair at the tip. At maturity the fruiting calyx of Russian thistle bears only one horizontal wing and is semi-indehiscent. In halogeton the dehiscent calyx has five prominent wings and the seed is borne vertically.

Halogeton first invades bare soils especially where the surface has been disturbed and thrives best where other vegetation is sparse or low in vigor. It is to be expected that it will continue to invade as it has in the past, the denuded areas being affected first. Unfortunately, such areas are all too abundant in the western states.

The precise ecological limits like the competitive potential of halogeton are still to be determined. Fear has been expressed that it might invade the central and even the eastern states. This seems improbable. In the absence of direct proof, its known present distribution and the bio-climatic limits of that environment can be given as a possible guide to its future distribution. Figures obtained as of March 1951 give the following estimated acreages of halogeton

infestations in the western states: California, 4,000 acres; Idaho, 268,000 acres; Montana, 2,500 acres; Nevada, 2,000,000 acres; Utah, 2,000,000 acres; and Wyoming, 300,000 acres, for a total of 4,754,000 acres (14). Increases in these states occurring during 1951 have not been reported except for a revised figure for Wyoming, which brings its total infested area to 767,000 acres (3) and an estimated increase in Idaho of about 20,000 acres.

Halogeton now occurs over a broad region in which annual precipitation ranges from 4 to 15 inches with the major portion falling during the winter months. The elevation varies from about 3,000 to 7,000 feet above sea level. Other characteristics of the infested region include a July relative humidity of 30 to 50 as compared to relative humidities of 55 to 75 for the central states. The soils of the infested area belong mainly in the northern grey desert and brown zonal groups and vary widely in texture, depth, and salt content. The vegetation belongs to the Intermountain shrub type, in which the dominant species include big sagebrush *(Artemisia tridentata)*, rabbitbrush *(Chrysothamnus spp.)*, and on the saltier soils or drier portions, shadscale *(Atriplex confertifolia)*, salt bushes *(Atriplex canescens and A. nuttallii)*, budsage *(Atriplex spinescens)*, greasewood *(Sarcobatus vermiculatus)*, etc. The principal grasses include squirrel tail *(Sitanion hystrix)*, wheat grasses *(Agropyron spicatum and A. dasystachyum)*, Sandberg bluegrass *(Poa secunda)*, and Indian ricegrass *(Oryzopsis hymenoides)*. Few grasses occur naturally on the areas of drier climate and saltier soils.

The future distribution of halogeton cannot be forecast with accuracy at this time. The above mentioned types of climate, soil, and plant cover are common to a large area, including most of Nevada, Utah, southern Idaho, southeastern Oregon, and western Wyoming, as well as smaller parts of western Colorado, and northern Arizona. The southern desert shrub zone to the south of this region, and the short grass plains which lie to the east also possess some of the same climatic and soil characteristics. Halogeton already is widely distributed over the Intermountain shrub zone, but whether it will invade all the above mentioned areas remains to be seen.

Its present distribution over widely recognized soil (16) and climatic (17) types and associations is graphically presented in the following figures. The evidence indicates that it is not extremely selective as to soil type or vegetative environment, but that it still must be considered as a weed of the more arid West.

The toxicity problem in halogeton remains as severe as ever, but the total mortality in livestock due to halogeton poisoning has declined from the high numbers recorded in 1942 to 1945. Some of the factors responsible for this condition include: (a) wide publicity regarding halogeton toxicity; (b) avoidance of severely infested areas and greater caution in grazing animals on halogeton-infested lands; (c) reduction in sheep numbers and grazing use on the worst halogeton areas; (d) the preparation of visual aids which have aided stockmen in identifying the plant (1, 8); and (e) perhaps sufficient

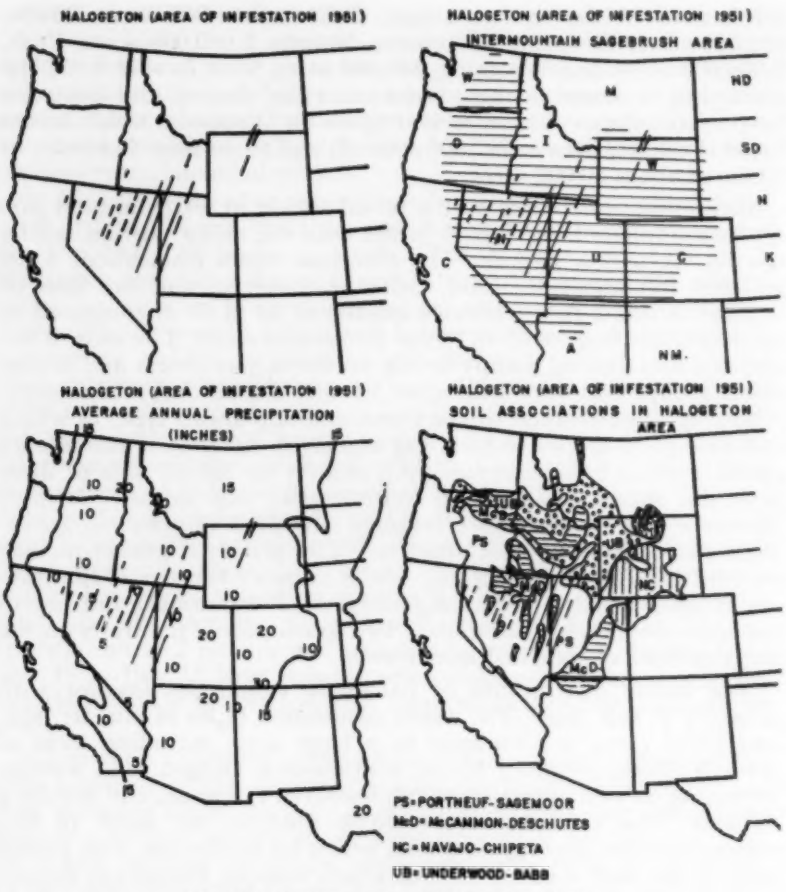

FIG. 3. Halogeton area of infestation 1951.

improvement in forage conditions in some areas to enable animals to obtain sufficient feed without eating halogeton. In this connection, it should be noted that studies have recently been started in Utah to determine what systems of livestock management can be used to minimize animal losses on halogeton infested areas.

It was first thought that the oxalates found in halogeton accumulated throughout the growing season, but analyses made recently at the University of Idaho indicate that the oxalate content on a dry weight basis is relatively uniform throughout the growth development of the plant. Leaching during winter has been said to be the factor responsible for reduced livestock losses, but losses have occurred in the spring also. There is evidence that the oxalates do leach (13) but it seems more likely under range conditions, that the

toxicity may be more directly associated with the proportion of leaves to stems at various intervals throughout the winter and spring months. Dye (6) and Morton (13) have found that the quantity of oxalates in the leaves of halogeton is approximately ten times that found in the stems. The oxalate content of entire plants usually varies from 18 to 22 per cent on a dry matter basis. Another interesting characteristic of this plant is its high ash content which includes relatively large amounts of several minerals. Although the toxicity factor in the plant is generally regarded as being directly related to its oxalate content, there are reasons to believe that other factors such as mineral content are involved also. The Nevada Agricultural Experiment Station which was first to conduct work on animal toxicity (9), now has a reactivated program in progress. Further information on toxicity should be forthcoming.

The halogeton problem has received considerable publicity, including information on its early history (6) and considerable progress has been made towards obtaining the basic facts necessary for its solution. More information is needed on nearly all phases of the problem, including means of: (a) retarding the present rate of spread; (b) revegetating presently infested areas; and (c) managing adjacent non-infested areas so as to prevent or at least retard the inroads of halogeton on them. Under present range conditions in the intermountain zone, relatively large areas are still susceptible to invasion by this weed. In Idaho alone, there are several million acres of such lands and the infestation of halogeton increased on them by some 20,000 acres during 1951. In addition, two new, small infestations were found — each over 100 miles away from the parent infested area in Cassia county. No doubt such small infestations will continue to occur in remote areas and constant vigilance will be required to find and eliminate them.

In conclusion, the following facts are important to keep in mind in connection with the halogeton problem: (a) The plant is still spreading and its ultimate area of distribution is not known at this time; (b) Land with a vigorous perennial cover of native or introduced vegetation is not likely to be invaded by halogeton; (c) Studies of control measures, while not yet complete, indicate good chances of success for reseeding programs and selective herbicides when properly handled; (d) Halogeton constitutes just one more problem in the complex business of managing the western range area. At present, it constitutes an important problem, but not a major catastrophe, and there is no reason to believe that it cannot be met and brought under control as have many other problems of our range lands.

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Sprayers for Use on Experimental Plots[1]

LYLE A. DERSCHEID[2]

INTRODUCTION

SINCE 2,4–D became recognized as a weed killer, thousands of experimental plots have been sprayed with this and numerous other chemicals. The various weed conferences have prescribed uniform experiments with uniform rates and dates of application, but there has been no uniform method of application. In order to apply the minute quantities of chemicals needed on small plots, it is absolutely essential that a constant pressure and speed be maintained and that uniform coverage of the entire plot be obtained.

The knapsack sprayer, which was used by many workers, was not entirely satisfactory for several reasons. First, it was almost impossible to maintain a constant pressure, because the air pressure and spray solution were in the same container. When the spray solution was discharged the air pressure decreased. Second, an operator had to practice for some time before he was able to walk the right speed to apply a given amount of chemical to a given area with a given pressure. Third, most knapsack sprayers were equipped with one or two nozzles, making it difficult to get uniform coverage of a plot that was wider than the swath covered by the one or two nozzles. Much of the error caused by these inaccuracies was overcome by applying relatively high volumes (40–80 gal. per acre) of spray solution per acre. This meant that the results from small plots could not always be duplicated in the field when only five to ten gallons of spray solution were applied to an acre.

Buchholtz (1) and Robinson and Dunham (2) have described pack-type sprayers equipped with a pressure tank, a pressure regulator and gauge, a spray-solution container and a one-nozzle boom. They were able to maintain a constant pressure and after some practice were able to maintain a constant speed. This sprayer made it possible to accurately apply low volumes of spray solution to a narrow band or row. However, it was necessary to use high volumes in order to get even coverage of wider plots.

Shaw (3) built a push-type sprayer, incorporating the desirable features utilized by Buchholtz (1) and Robinson and Dunham (2), and added others. He added a speedometer and an eight-foot boom which was adjustable for height. He was able to maintain constant pressure and speed and could obtain uniform coverage, with low volumes of spray, over an eight-foot swath.

The purpose for building the sprayers described in this paper was to secure mobile sprayers that utilized the desirable features men-

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tioned above. A light-weight push-type sprayer that could be transported in a minimum of space was designed for use on small plots, and a trailor sprayer that could be trailed from one experimental area to another was designed for use on large plots. These two sprayers are discussed separately.

Push-Type Sprayer

An over-all view of the sprayer is shown in Figure 1. Since it is necessary to transport the sprayer together with stakes, water cans, chemical containers and an air compressor, it was necessary to construct the sprayer of light material, with maximum dimensions of three and one half feet in height, three and one half feet in length and less than four feet in width. It was also necessary to make the boom detachable, and to build supports to keep the sprayer in an upright position while in transit. The frame is constructed of three fourths inch conduit, the wheels are heavy duty bicycle wheels, the air-pressure tank is a war surplus air corps oxygen tank, four spray containers are two-quart oil filter cases, one spray container is a one-gallon oil filter case, the boom-support is made of $1\frac{1}{4}'' \times \frac{1}{8}''$ angle iron, and the weight of the sprayer with the boom detached is

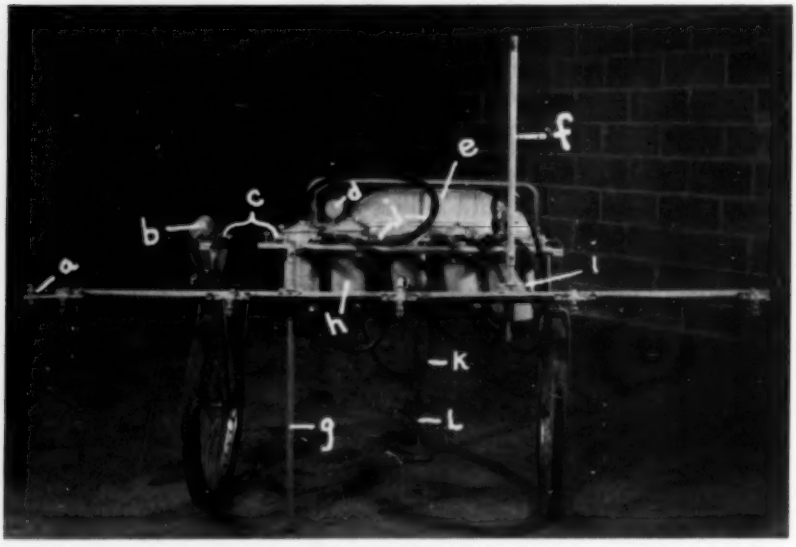

FIG. 1. An over-all view of the push-type sprayer showing: (a) drain valve on boom, (b) speedometer, (c) left wheel in extended position, (d) pressure gauge, (e) air supply tank, (f) front leg in "up" position for spraying, (g) front leg in "down" position for transporting, (h) small spray container, (i) large container for spray solution or flushing solution, (j) speed coupler and hose connecting air supply tank to spray tank, (k) hose from spray tank to boom and (l) rear leg in "down" position.

95 pounds. The machine is kept in an upright position with two legs in front and one behind. The front legs are of one half inch pipe three feet long and are used as supports for the boom when the sprayer is in operation. The rear leg is made of one half inch conduit; it is telescoped into a sleeve and can be raised straight up when spraying. The pressure regulator is a simple diaphragm regulator and the speedometer was built for use on a tractor. The total retail cost of material used is approximately $225.00.

Each wheel is attached to the frame by means of an old bicycle fork, a piece of three fourths inch pipe, a short piece of one and three fourths inch x one eighth inch angle iron, two 1¾″ strap-iron braces and two ¾″ rods one and one half feet long. The fork is attached to the angle iron with the pipe and strap-iron braces. Wide braces were needed to keep the wheel in alignment. The angle iron is welded to the two ¾″ rods which telescope inside the conduit frame and are held in position with thumb screws, making it possible to adjust wheel width.

The boom-support is seven feet long. However, the spray solution passes through a three eighths inch oil resistant hose that connects the five nozzles, which are attached to the boom-support by means of special nozzle brackets. The boom-support is welded to hinges which are in turn welded to sleeves which can slide up and down on the front legs of the machine (Figure 1). Set-screws are used to set the sleeves at the desired place on the legs. The legs also slide up and down in sleeves which are welded to the frame. The legs are kept at the desired height by use of set-screws in the second pair of sleeves.

SOURCE OF PRESSURE AND SPRAY SUPPLY

Since a small air compressor, needed for other uses, was on hand, compressed air was used as a source of pressure. The air supply tank is tested for 250 pounds pressure per square inch. It is recharged to about 100 pounds pressure from the compressor left in the truck. The recharging takes about five minutes. As shown in Figure 1, the air supply tank is connected to any one of the spray supply tanks by means of a ⅜″ oil resistant hose and an air-hose speed coupler. A pressure regulator, pressure gauge and three-way valve are in the line as shown in Figure 2. A pressure within the range of five to 100 pounds per square inch can be used, but 30 pounds per square inch is the most common. The three-way valve directs air to the spray tank, when open, and releases the head of air pressure in the spray tank, when closed. This release of pressure eliminates any dripping from the nozzles, which are also equipped with no-drip screens; but it is somewhat wasteful of air pressure. However, 50 eight-foot x 15-foot plots can be sprayed with one tank of air.

Any one of the spray containers can be connected to the boom (Figure 1) with a one half inch oil resistant hose and another air-hose speed coupler. When a spray tank becomes empty, it can be

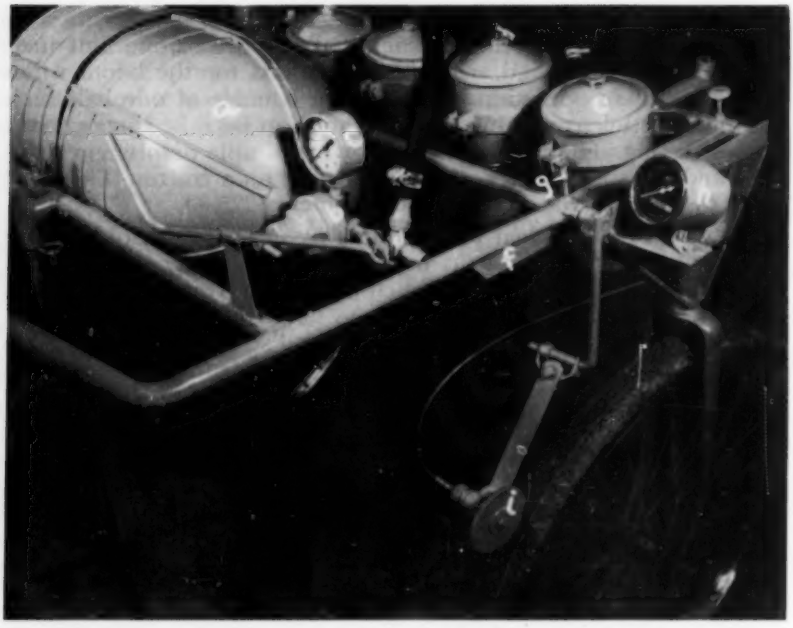

FIG. 2. Close-up of sprayer showing: (a) air supply tank, (b) pressure regulator, (c) pressure gauge, (d) 3-way valve, (e) small spray container, (f) reinforcing strap, (g) thumb-screw for setting wheel width, (h) speedometer dial and (i) speedometer drive.

taken out of the line by disconnecting two speed couplers. A full tank can then be put into the line by connecting two speed couplers. One of these containers will hold enough spray solution to cover six square rods at 13 gallons per acre, four square rods at 20 gallons per acre or two square rods at 40 gallons per acre.

MAINTAINING CONSTANT SPEED

The speedometer, which is calibrated in increments of two-tenths of a mile per hour is mounted where it is clearly visible to the operator (Figure 2). The speedometer is driven by a small wheel that runs on the face of the tire, which gives the same effect as would be given if the small wheel were in contact with the ground. It is therefore possible to use this speedometer on any size wheel as long as it is in contact with the face of the wheel as shown in Figure 2.

OBTAINING UNIFORM COVERAGE

Five nozzles that deliver an 80°-angle, fan-shaped spray pattern are spaced 19¼ inches apart and give even coverage over an eight-foot swath. The boom can be lowered to a height of 20 inches which

gives uniform coverage for preemergence applications; or it can be raised to any height up to five feet, which will give uniform coverage of any foliage up to three and one half feet in height.

"Teejet" and "Sprajet" nozzles are used so that a change in volume can be obtained by changing nozzle tips. No-drip screens are used to help prevent dripping when the air pressure is shut off. Since it is necessary to carry several sets of tips in the tool box, the "Sprajet" tips are preferred because the no-drip screens can be screwed in the tips and left there. This eliminates the possibility of collecting sediment in the tips, which would interfere with the output of the tips when they are put in use.

FLUSHING THE SYSTEM

The entire system can be cleaned quickly, so that all traces of one spray solution can be removed before the next one is used. Six spray tanks are used – two are being filled at the truck, while the four are on the machine. When a spray tank is emptied it is taken out of the machine, replaced with a full one, washed and refilled. By rotating the six spray tanks, two men can wash and refill as fast as one man can spray.

The boom is mounted on hinges so that it can be tipped up to drain the nozzles into the hose portion of the boom. The hinges are off-set so that when the boom is tipped, one end is higher and all the solution in the boom drains through the valve at the lower end. The air supply tank can be connected directly to the boom to help clean it, or the one-gallon spray tank can be filled with a flushing solution for cleaning it.

ADAPTATION TO EXPERIMENTAL PLOTS

Experiments involving the study of the effects of chemicals on a crop are conducted on regular weed-free nursery plots (small grain on four-row x 14-foot plots, corn on two-row x 10-hill plots, and sorghum on two-row x 25-foot plots) while studies involving the use of chemicals on perennial weeds are conducted on plots 16 feet x 16 feet in size. Plots of grain infested with annual weeds are five feet x 15 feet in size, which permits the use of a field tractor for cultivating two-foot allies between plots; whereas, plots of annual weeds are either five feet or eight feet wide depending on the space available.

This sprayer is readily adaptable to all of these plot sizes. The entire boom is used when spraying plots eight feet wide and two swaths will cover a 16-foot plot. The middle three nozzles cover a five-foot plot; whereas, two nozzles can be used to spray row crops. Wheel width can be extended to straddle five-foot plots or two-row plots. One nozzle will cover the middle two rows of the four-row small grain plots if the boom is raised slightly higher than normal, and wheel width can also be adjusted to straddle these four-row plots.

SUGGESTIONS FOR IMPROVEMENT

The most important change would be the addition of a flowmeter to measure the exact amount of solution applied to each plot. A second improvement would be to reduce the minimum width to about 32 inches. The sprayer could then be operated between corn rows and would be much easier to operate than it is when the rows are straddled.

A third improvement is a reinforcement measure. The conduit cross-pieces (one in front of the spray tanks and one behind the spray tanks) are joined together by a small channel iron, and both cross-pieces split at the weld. The rear cross-piece has been reinforced (Figure 2) by welding a strap-iron edgewise along the bottom of the handle and the channel iron. This strap-iron could be extended forward to reinforce the front cross-piece if the front leg attachment were placed on the frame directly in front of the channel iron.

A fourth improvement would be on the spray tanks. Where possible it would be advisable to use smaller containers so that less air pressure would be wasted when the head of air in the spray tank is released. The oil filter cases used as spray tanks are sealed with rubber gaskets, which have to be replaced frequently. It is also necessary to use a wrench to seal and unseal these containers. A cheaper case can be obtained which appears to be more desirable for this use. It is somewhat smaller, is sealed with a permanent gasket and is opened and closed with a wing-nut.

Trailor Sprayer

Four round 20-gallon tanks, which can be used independently were mounted on a two-wheel trailor equipped with springs as

FIG. 3. Overall view of trailor sprayer, showing one section of the boom extended for spraying and the other section folded up for transporting.

shown in Figure 3. A bronze gear-pump, pressure regulator and gauge, flow meter, speedometer and boom that is adjustable for height are utilized to secure constant pressure and speed and uniform coverage. The boom is divided into two sections so that it can be folded forward when in transit.

CONSTANT SPEED AND PRESSURE

Constant speed is maintained by setting the speed of the tractor used to draw the sprayer. Setting the tractor speed is facilitated by the use of a tractor speedometer that is mounted on the sprayer. This speedometer is like the one used on the push-type sprayer. The drive wheel is in contact with the right wheel of the sprayer, but it is attached so that the contact can be broken when the sprayer is not actually spraying.

The source of pressure is a bronze gear-pump driven by an auxiliary gasoline motor. Pressure is regulated with a pressure gauge and a diaphragm regulator attached to the pump. This regulator retains excess solution in the pump and does not utilize a by-pass to the spray supply tank.

UNIFORM COVERAGE

Ten nozzles, each delivering an 80°-angle, fan-shaped pattern are spaced at 20-inch intervals on the boom so that the sprayer will cover a 200-inch swath. Each of the two sections is constructed exactly like the one used on the push-type sprayer. Boom height can be adjusted from a low of 20 inches for preemergence applications to a high of five feet for foliage treatments. Therefore, uniform coverage can be obtained on foliage that is three and one half feet or less in height.

Volume changes are obtained by changing nozzle tips as outlined for the smaller sprayer. Dripping at the end of plot is controlled by shutting off both sections of the boom and by using spring-loaded, no-drip screens in the nozzles.

The sprayer is calibrated to deliver a certain volume per acre, but a flow meter, calibrated in increments of $^1/_{20}$ of a gallon, is used to check the exact amount of chemical applied to each plot. The sprayer is turned on just before the boom reaches the plot and flow meter reading is noted; the sprayer is turned off as soon as the plot is finished and the flow meter reading is again noted. The exact amount applied is recorded if it is not the amount intended. For example; 6.25/20 of a gallon should be applied to a plot one rod x five rods in size when 10 gallons are being applied to an acre. If any other amount is applied, it is noted and the exact amount of chemical applied is determined.

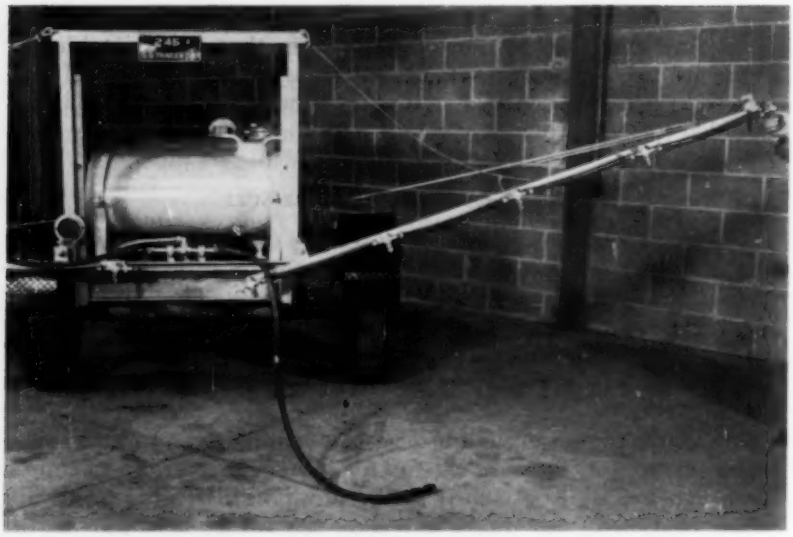

FIG. 4. Rear view of sprayer showing how the system is cleaned.

FLUSHING THE SYSTEM

The only filter in the system is a coarse screen, which is not a hindrance in the rapid cleaning of the system when changing solutions. The hoses can be detached from the two sections of the boom with speed couplers as shown in Figure 4. These hoses can be dropped on the ground and drained, and the boom can be drained by lifting the outer end and draining through a valve at the inner end. If another solution of the same chemical or a solution of a similar chemical is to be used next, some of this solution can be pumped through the system. This forces out remaining traces of the former solution. However, it is possible to use one tank as a container for a flushing solution if it is necessary to do a more thorough job of cleaning the system. Each tank has a drain at the bottom so that it can be completely drained.

ADAPTABILITY TO FIELD PLOTS

The wheel width is extensible from a standard width of about five feet up to seven feet, making it adaptable to row-crop spraying. However, the low clearance, which is made necessary when leaf springs are used, precludes the possibilities of spraying tall row crops. Both sections of the boom can be used simultaneously for use on one-rod plots, or one section can be used at a time for use

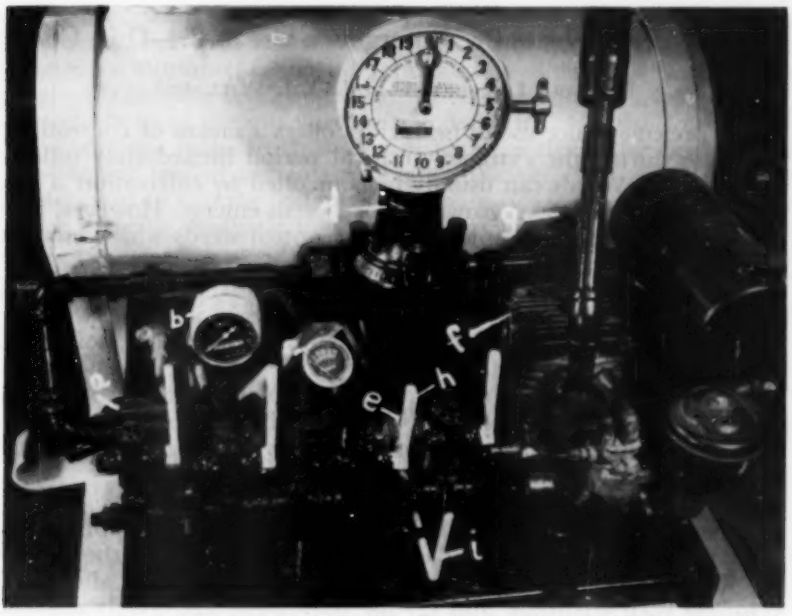

FIG. 5. Close-up of the controls showing: (a) simple filter, (b) speedometer dial, (c) pressure gauge, (d) flow meter, (e) pump, (f) auxiliary motor, (g) outlet for connecting brodjet or hand boom, (h) one of four levers which control the four tanks and (i) boom control lever.

on 8-foot plots. Both boom sections can be shut off and a brodjet boom mounted at the front of the sprayer for brush or roadside spraying. A hand-boom can also be connected into the line for patch spraying. By using a different solution in each tank, it is possible to spray as many as 200 plots in an afternoon.

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Factors Affecting the Pre-Emergence Use of 2,4–D in Corn[1]

RICHARD J. ALDRICH[2] and C. J. WILLARD[3]

THE pre-emergence use of herbicides offers a means of controlling weeds during the extremely critical period immediately following planting. Weeds can usually be controlled by cultivation if the crop makes a few weeks' growth before weeds emerge. However, it is practically impossible to mechanically control weeds which emerge ahead of or with the crop.

Most discussions of pre-emergence 2,4–D treatments in corn, before scientific and before farmer meetings, begin and end with an "if" clause regarding rainfall, time of 2,4–D application, soil type, and other factors. A good many of these "if" clauses could be eliminated with fundamental information on the various factors involved in the pre-emergence use of 2,4–D. Certainly treating corn pre-emergence will not be accepted as a common farming practice until some of these "ifs" are removed.

All of the acknowledged factors which affect results of pre-emergence 2,4–D treatments in corn including time of application, soil type, rainfall, locality, and others are related to one of the following fundamental factors: (1) the manner in which 2,4–D affects developing corn seedlings, and (2) the movement and availability of 2,4–D in soil.

There is no literature directly related to the manner in which 2,4–D affects developing corn seedlings. Mitchell and Brown (5) found that mustard seedlings with radicles 5 millimeters long were more susceptible to 2,4–D injury than seedlings in earlier stages of germination, and seeds were relatively unaffected. Several investigators (1, 2, 10) have found that delaying 2,4–D application a few days after planting lessens the hazard of reducing corn stands. These studies suggest that the susceptibility of corn seedlings to 2,4–D injury may vary with stage of germination. In the present investigation the manner in which 2,4–D affects developing corn seedlings was studied by the following means: (1) germinating and growing corn in pots in which 2,4–D was placed at different levels with respect to the seed, (2) direct application of 2,4–D to seeds and different parts of germinating corn seedlings, and (3) applying 2,4–D on successive days after planting corn in pots.

Numerous reports in the literature suggest that 2,4–D may be fixed on the soil colloids. The early work of Nutman, *et al.* in England (6) showed that 2,4–D was more toxic to germinating sugar beet,

[1]Part of a dissertation submitted to the Faculty of the Graduate School of The Ohio State University in partial fulfillment of the requirements for the degree Doctor of Philosophy.

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red clover, and wheat seedlings growing in a light sand low in organic matter than when growing in a clay loam high in organic matter. In a comprehensive laboratory study of eight California soils Crafts (3) found a tendency towards decreased initial 2,4–D toxicity to test plants as the soil particle size decreased. He also found that 2,4–D did not move freely with moistening water in his percolation studies but tended to remain behind. Weaver (9) was able to decrease, and in certain instances eliminate, toxic effects of 2,4–D in soil by adding synthetic ionic exchangers to the soil.

EXPERIMENTAL

Movement and fixation of 2,4–D in soil was studied by the following means in the present investigation: (1) mixing 2,4–D solutions of known concentration with a mixture of sand and a naturally occurring montmorillonitic-type of clay and measuring the concentration of 2,4–D in the supernatant liquid after centrifuging, (2) measuring the 2,4–D concentration in the filtrate collected beneath different depths of soils through which 2,4–D solutions of known concentration were leached, and (3) irrigating in the field immediately after applying salt and ester formulations of 2,4–D.

EFFECT OF 2,4–D ON GERMINATING CORN SEEDLINGS

2,4–D location with respect to seed

Methods – Corn seeds were planted in cans containing sand and 2 and 4 pounds (acre-area basis) of a tri-ethanolamine salt of 2,4–D were applied an inch below the seed, at the seed level, and at the soil surface to separate cans. To prevent downward movement of 2,4–D applied to the soil surface, cans with this treatment were watered by immersing in water and bringing water up to the seed level. In the remaining cans sufficient water to wet to the seed level was added to the surface. Each treatment was replicated five times. After stand counts were recorded for each can seedlings were removed and examined for 2,4–D effects.

Results – Corn stands were reduced only in those cans which received 2,4–D at the seed level as seen in table 1. Seedlings which

Table 1. The effect of 2,4–D location and rate on emergence of corn.

2,4-D location	Plants per container†	
	5 Seed 2 lbs. 2,4-D/A	10 Seed 4 lbs. 2,4-D/A
Soil surface		
Treated	4.7	9.2
Untreated	4.0	9.7
Seed level		
Treated	5.0	1.2
Untreated	4.7	9.9
Below seed		
Treated	5.0	8.8
Untreated	5.0	9.0

†Average of five containers.

emerged in cans treated with 2 pounds of 2,4–D at the seed level did not survive. When the seedlings were removed and examined those from cans treated at the soil surface were not significantly different from the check. Roots did not penetrate beyond the 2,4–D layer placed one inch below the seeds. In addition root tips which came in contact with the 2,4–D below the seed were enlarged and dark brown in color indicating abnormal cell division in this region. The test shows that it was necessary for 2,4–D to penetrate to the seed to reduce corn stands. The results suggest also that rates of 2,4–D used in pre-emergence applications may inhibit root growth of corn seedlings if 2,4–D is in contact with the growing tips.

2,4–D application to seeds and seedlings

Methods – 2,4–D impregnated lanolin was applied to corn seeds; one-half were treated on the embryo side and the remaining were treated on the side opposite the embryo. A small cut was made in the seedcoat beneath the lanolin drop in one-half of the seeds. After applying the 2,4–D the seeds were placed on moist blotter papers in a germinator.

Corn seedlings were treated with 2,4–D impregnated lanolin at the following locations: the root tip, the root hair region, the transition zone lying between the root and the shoot, and the shoot tips. Following treatment the seedlings were returned to moist blotters in the germinator.

Results – 1. Seed treated: Applications to the side opposite the embryo had no effect on germination and seedling development. In seeds treated over the embryo the radicle and plumule broke through the seedcoat but further growth was prevented. Rupturing the seedcoat did not affect the results which indicates that the dormant embryo was relatively tolerant of the rate of 2,4–D used.

2. Root tip treated: 2,4–D prevented further elongation of the treated root. No formative effects were produced on shoots.

3. Root hairs treated: 2,4–D retarded elongation of the treated root but did not stop it completely. No formative effects were produced on shoots.

4. Region back of root hairs treated: Elongation of the root was slightly retarded but not as much as from treatments at the tip and in the root hair region. No formative effects were produced on shoots.

5. Transition zone treated: Epinasty of the shoot was severe. Elongation of the primary root was retarded and secondary roots did not develop. Apparently 2,4–D was translocated in both directions from the area treated. This is compatible with the findings of Rice, *et al.* (8) and Mitchell, *et al.* (4) concerning the movement of 2,4–D with carbohydrates.

6. Shoot tip treated: The growth of leaves in the bud within the coleoptile was inhibited. Roots were not affected.

2,4–D application on successive days after corn planting

Methods – Ten corn seeds were planted one inch deep in each of

eight cans containing moist sand. Sixty-five cc. of a 55 ppm 2,4–D amine solution (equivalent to 4 pounds per acre) were added to the first can in the series on the day of planting, to the second can the day after planting, and so on through 7 days after planting. Seedlings were beginning to emerge on the 7th day after planting. The amount of solution added was sufficient to wet approximately ¾ inch below the seed. After stand counts were recorded the seedlings were removed from the cans and examined for 2,4–D effects.

Results – Stands were reduced only by the treatment made the day the corn was planted. The aboveground parts of plants which emerged in cans treated after the first day showed 2,4–D injury symptoms in the form of epinasty, splitting of stems, and reduced growth. The injury decreased in direct proportion to the time which elapsed between planting and 2,4–D application. The aboveground parts of plants which emerged in cans treated 7 days after planting showed no 2,4–D effects.

On examination of the roots, it was found that the degree of shoot injury was proportional to the root inhibition. The roots on seedlings from cans treated the first and second day after planting were very restricted. The degree of root inhibition decreased with subsequent treatments. Roots on seedlings treated 7 days after planting were as long as the checks although secondary roots were not as numerous.

It appeared that the process of new root formation was equally susceptible to 2,4–D injury at all stages investigated. The extent of root development at the time of 2,4–D application, as it determined the absorbing root area, was the factor which controlled the further development of the seedling as a whole. Treating shortly after corn planting stopped root development and the root system present at that time was too small to support the further development of the seedling. As the interval between planting and treating increased the point was reached at which roots were large enough to support further plant development although 2,4–D restricted further root growth.

AVAILABILITY AND MOVEMENT OF 2,4–D IN SOIL

The seedling studies showed that stand reduction or reduced growth resulting from a pre-emergence 2,4–D treatment could occur only if the 2,4–D leached at least to the seed. This suggested that any factor which tends to restrict the downward movement of 2,4–D in soil would lessen the chance of injury from pre-emergence 2,4–D.

The movement of ester and salt formulations of 2,4–D and possible fixation on soil colloids were investigated in the present study since both would have an effect on results of pre-emergence applications.

2,4–D fixation

Methods – Known concentrations of a triethanolamine salt and a butyl ester formulation of 2,4–D were added to a mixture of sand

and a naturally occurring montmorillonitic type of clay. The concentration of 2,4–D in the supernatant liquid was measured by means of the bio-assay using cucumber seeds (7). A lower concentration of 2,4–D in the supernatant liquid than that in the solution added would be an indication of fixation by the clay.

The soil residue in the tubes was washed five times with distilled water, following the initial procedure of shaking, centrifuging, and assaying the supernatant liquid. By recording the volume of each washing it was possible to calculate the amount of 2,4–D removed in the washings.

Results – The difference in 2,4–D concentration between the solution added and that found in the supernatant liquid is shown in table 2. From the column headed "First liquid decanted" it is seen

Table 2. Effect of a 50 per cent clay-sand mixture on the "fixation" of 2,4–D from 5 ppm solutions.

Form of 2,4-D	Ppm of 2,4-D in supernatant liquid			Per cent of 2,4-D removed in decanted solution
	First decanted solution	Composite of first 4 washings	Fifth washing	
Butyl ester	0.05	0.05	0.07	4.9
Amine salt	1.20	0.80	0.50	74.5

that the concentration of both 2,4–D formulations was decreased by the sand-clay mixture. Although this suggests fixation by the soil colloids it was found that 74.5 per cent of the amine was removed in the initial decanted solution plus five washings. It is possible that the reduction in amine 2,4–D concentration represents conversion to a less soluble 2,4–D form rather than actual fixation by the colloids. The ester was not readily removed by washing and the best inference is that the reduction in concentration with the clay is the result of some type of fixation. Regardless of the mechanism involved, the data suggest that ester formulations would tend to be less mobile in soils than salt formulations.

Movement of 2,4–D in soil

Methods – An emulsion of a butyl ester formulation and solutions of a sodium salt, triethanolamine salt, and acid formulations of 2,4–D having a concentration of 10 p.p.m. were allowed to filter through various depths of sand and 50 per cent clay-sand mixtures. The concentration of 2,4–D in the filtrate collected was measured by means of the bioassay using cucumber seeds.

Results – The movement through soil of the 2,4–D formulations used is shown in table 3. One-half inch of the clay-sand mixture was sufficient to remove practically all of the butyl ester; roughly comparable to the amount of 2,4–D amine, acid, and sodium salt coming through 2 inches of the clay-sand mixture. Only 0.4 p.p.m. of 2,4–D were present in the filtrate from sand leached with 10 p.p.m. of the

Table 3. Effect of filtering 10 ppm "solutions" of four 2,4–D forms through varying depths of sand and of 50 per cent clay-sand mixtures on growth of cucumber roots.

Form of 2,4-D	Filtrate from 1 inch of clay-sand		Filtrate from 2 inches of clay-sand		Filtrate from 2 inches of sand	
	Cucumber root length	2,4-D concentration	Cucumber root length	2,4-D concentration	Cucumber root length	2,4-D concentration
	mm	ppm	mm	ppm	mm	ppm
Butyl ester	69.3 ± 2.1†	<0.1†			57.8 ± 1.4	0.4
Amine salt	55.4 ± 1.9	0.1	66.3 ± 3.0	<0.1	17.8 ± 1.2	>5.0
Na salt‡	45.8 ± 1.7		66.6 ± 1.7		17.4 ± 0.9	
Acid‡	45.9 ± 2.3		70.6 ± 2.2		21.3 ± 1.1	

†Only one-half inch of clay-sand.
‡Curves were not obtained for growth in known concentrations making it impossible to calculate the 2,4-D concentration in the filtrate.

ester, whereas, more than 5 p.p.m. were present in the filtrate from sand leached with 10 p.p.m. of the amine. Without diluting, the bioassay used would not measure concentrations greater than 5 p.p.m. so that actually it is quite possible that the concentration for the amine was not reduced significantly from the 10 p.p.m. added. The pronounced difference between the ester and amine is probably due to differences in physical properties of the spray. The emulsion which the ester forms with water would break on contact with soil. The amine, sodium salt, and acid, which are true solutions in water, would be expected to move more freely with percolating water. Since it was found that 2,4–D must reach the seed to prevent germination it would seem that ester formulations would be less likely to reduce corn stands when applied pre-emergence than would the other forms.

Movement of 2,4–D Ester and Amine Forms in Soils Under Irrigation

Methods — An irrigation test was established to check in the field data which had been obtained in the laboratory seedling and soils studies. New Jersey #7 hybrid corn was planted 2½ inches deep in a loam soil of the Nixon catena. The plots were 1 x 14 hills in size and were replicated seven times. 2,4–D application (36 hours after planting) was delayed until the majority of seeds had started to germinate, i.e., the radicle just beginning to emerge from the seedcoat, since laboratory seedling studies showed that corn emergence was prevented only if 2,4–D was present during this early stage of germination. Four pounds to the acre of a butyl ester and an amine salt formulation of 2,4–D were applied and then sufficient water was added by irrigation to wet down just to the corn seeds. Corn stands and plant height were recorded approximately four weeks after emergence.

Results — The effects of the two formulations on corn stands and plant height are shown in table 4. The amine salt resulted in highly significant reductions in stand whereas the ester did not reduce stands significandy. This bears out results obtained in the laboratory studies.

Table 4. Effect of four pounds of 2,4–D to the acre, applied pre-emergence, on stands and growth of corn five weeks after planting.

Treatment	Plants per plot	Plant height (inches)
Butyl ester	45.7	34.1
Amine salt	37.4	32.7
Check	48.8	38.9
L.S.D. .05	4.0	2.1
L.S.D. .01	5.6	2.9

DISCUSSION

It was found that 2,4–D must be at the seed during the early stages of germination to reduce corn stands. The ester by virtue of its being fixed to a greater extent by clay and also by virtue of its being relatively water-insoluble, does not reach the seed as easily as the salts. Since a reduction in corn stands is the most serious injury possible from a pre-emergence 2,4–D treatment, this difference contains very important implications for the field use of these materials.

Results obtained in the present study showing a difference between ester and salt formulations for pre-emergence application are contrary to other field results reported for such treatments. Probably previous experiments did not provide conditions necessary to detect differences between formulations. If no rain falls between 2,4–D application and corn emergence, stands would not be reduced by either formulation. At the other extreme, if heavy rains immediately follow an ester and amine treatment, it is possible that the amine might leach beyond the seed whereas the ester might not reach the seed. Again neither formulation would be expected to reduce emergence of the corn. In an irrigation study it is evident that careful attention would have to be given to the timing of the water application for the differences to be detected.

Although it is difficult to detect differences between formulations in field experiments the differences are nevertheless of considerable practical importance.

Timing the application would not be so critical with the ester. It is well established that 2,4–D can safely be applied pre-emergence if the application is delayed until just prior to corn emergence. However, from a practical standpoint this is a very difficult thing to recommend to farmers, for they must make their applications when weather and labor permit. If treatment is delayed to allow for safe application, there is a greater possibility of rain interfering. If an ester could be safely applied at the time of planting it would then be possible to make the application at the same time the corn is being planted, perhaps in one operation. If and when the time ever comes that 2,4–D can be applied in this way a much greater number of farmers will use it for weed control in their corn.

Since the esters did not leach freely in straight sand, it would seem worthwhile to investigate further the pre-emergence use of esters on some of the lighter sandy soils. At the present time 2,4–D is not

recommended as a pre-emergence treatment for corn on light sandy soils.

Ester formulations may provide effective weed control more consistently than salts since the esters are not leached as readily from the surface layer of soil. Further research is needed to establish this possibility.

Pre-emergence 2,4–D may be safely and economically used to control many annual weeds in corn with the proper selection of 2,4–D formulation. Continued intensive study of new chemicals will undoubtedly establish this method of application in many crops in addition to corn.

SUMMARY

1. 2,4–D prevented corn emergence only when it was in contact with the seed during the early stages of germination.

2. The dormant corn embryo was more resistant to 2,4–D injury than it was after germination began.

3. The 2,4–D ester did not move as freely with percolating water as did salt forms. This is due to an apparent fixation of the ester on the clay and also to the fact that the emulsion which the ester forms breaks on contact with the soil.

4. Four pounds to the acre of 2,4–D butyl ester applied 36 hours after planting did not significantly reduce corn stands whereas an equal quantity of an amine salt resulted in a 23 per cent stand reduction when sufficient water was applied to wet the soil to seed depth immediately following spray application.

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Cultural Methods for Control of Quackgrass[1]

H. J. Lowe and K. P. Buchholtz[2]

Quackgrass *(Agropyron repens)* is a weed of major importance in the northern regions of the United States where cool, humid climatic conditions prevail. In the areas of Wisconsin having a heavy red clay soil, the weed is especially troublesome for the soil characteristics hinder the most effective use of cultural control measures. The fact that quackgrass can be found on the majority of the farms in northern Wisconsin is evidence that effective methods of quackgrass control are not being used. The question arises of whether generally recommended methods of quackgrass control are effective under the conditions prevalent in this area. The present study describes the results obtained during 1947 and 1948 at the Ashland Branch Experiment Station using several combinations of tillage, cropping and fertilization. An attempt was also made to compare the value of two methods of estimating quackgrass infestations.

Literature Review

Cultural control of quackgrass is generally obtained by a reduction of organic reserves in the rhizomes, by desiccation of the rhizomes, or by a combination of the two factors. Dexter (3) was of the opinion that depletion of organic reserves in the rhizomes is the predominant factor involved when quackgrass sod is plowed and then disked frequently to prevent foliage development. In earlier studies, Dexter (2) and Johnson and Dexter (4) found that fertilization with nitrogen greatly stimulated shoot development in quackgrass and that the rhizomes of fertilized plants seemed to be more susceptible to soil fungi. The increased shoot growth obtained after fertilization undoubtedly accelerates the rate of organic reserve depletion. The work of Pinckney (5) in North Dakota indicates that the levels of organic reserves in quackgrass do not fluctuate markedly during the year. Consequently, the period of initiating cultivation for control of quackgrass by depletion of reserves does not appear to be critical. Reduction in organic reserves may also be assumed to be the main factor involved when smother crops are planted on infested areas.

Dexter (3) has shown that quackgrass rhizomes were killed readily by desiccation when exposed to dry air of moderate temperature. The effects of drying were found to be more injurious to rhizomes obtained from field plots in late spring and early summer than those obtained either earlier or later in the season. Dexter (2) also showed that fertilization with nitrogen had no effect on the susceptibility of rhizomes to desiccation if they had not been reduced previously in organic reserves by excessive shoot growth.

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An attempt was made by Arny (1) and by Dexter (3) to express the degree of quackgrass infestation in plots by determining the weights of rhizomes contained in the soil beneath quadrats. Detailed studies of quackgrass control using this method of determining infestations do not appear to have been used by other workers. Stoa et al. (6) expressed the control of quackgrass obtained in an extensive study in relative terms. Similar methods which do not give absolute values of infestation have been used by most workers who have considered the problem of quackgrass control.

MATERIALS AND METHODS

The experimental area used in the present study was an old alfalfa and timothy sod infested heavily and uniformly with quackgrass. The soil type was Ontonagon silty clay of medium fertility located on the Ashland Branch Experiment Station. A two-way whole plot design with four replications was used. The size of individual plots was 100 by 37 feet. Cultural treatments consisted of (1) sowing oats, the prevalent practice in the area, (2) sowing sunflowers as a smother crop, (3) consistent cultivation with a spring-tooth field cultivator, and (4) plowing followed by repeated disking. Fertilization treatments used were (1) none, (2) application of 200 lbs. of ammonium nitrate per acre and (3) application of 600 lbs. of ammonium nitrate per acre. All fertilizer applications were applied on May 20th before planting the oats. The fertilizer applications were made at right angles to the cultural treatments which necessitated the use of the two-way whole plot design.

All of the various treatments were begun in the spring or summer of 1947. The plots sown to sunflowers and oats were plowed on May 8. The oat plots were sown on May 20 using three bushels of Vicland oats per acre. Mammoth Russian sunflowers were sown at the rate of 60 lbs. per acre on June 1 using a grain drill. This resulted in a sunflower stand with plants spaced about 8 inches apart in the row. The remaining plots were left in hay which was harvested on July 1 prior to plowing and disking or to cultivation. The first spring tooth cultivation was made to plots subjected to this treatment on July 12. The cultivations were repeated at weekly intervals for a six-week period. Plots subjected to disking were first plowed to a depth of seven inches and then disked at weekly intervals for a similar six weeks period.

Estimates of quackgrass infestations were obtained by determining the presence or absence of above ground shoots in small quadrats or by determining the length of live quackgrass rhizomes buried in the soil beneath quadrats. Quadrat infestations were obtained from 50 one foot square quadrats selected at random in each plot. The presence of one or more above ground shoots of quackgrass in each quadrat was regarded as evidence of infestation. The infestations are tabulated as the percent of the quadrats showing infestation. The soil beneath every fifth quadrat was dug to a depth of seven inches and the live rhizomes sorted or washed from the soil. The total

Table 1. Quack infestations before and after cultural treatments using two methods of estimation.

Treatment	Date of estimation	No fertilizer		200 lbs. ammonium nitrate/A		600 lbs. ammonium nitrate/A		Average	
		Rhizome length	Quadrats† infested	Rhizome length	Quadrats† infested	Rhizome length	Quadrats† infested	Rhizome length	Quadrats† infested
		In. per sq. ft.	Per cent	In. per sq. ft.	Per cent	In. per sq. ft.	Per cent	In. per sq. ft.	Per cent
Cultivation	1947	317	100	291	100	291	100	299	100
	1948	1	11	1	11	1	12	1	11
Plowing & discing	1947	319	100	317	100	291	100	309	100
	1948	89	81	49	62	33	51	57	65
Sunflowers	1947	296	100	274	100	272	100	281	100
	1948	127	99	102	99	66	98	98	99
Oats	1947	327	100	362	100	331	100	340	100
	1948	147	100	153	99	94	91	131	97
Average	1947	315	100	311	100	296	100	307	100
	1948	91	73	76	68	49	63	72	68

†Fifty one-foot square quadrats per plot.

length of rhizomes contained in each soil sample was measured and the data are expressed as the average length of rhizomes contained beneath each square foot of soil in the treatment. The initial determinations of infestation were made from April 30 to May 6, 1947. The final determinations were made from April 28 to May 4, 1948.

RESULTS

Data in Table 1 show that all plots were heavily infested with quackgrass before treatment. Both methods of estimation gave comparable figures at this time although the data on rhizome measurements indicate the degree of infestation more precisely. Working the plots with a field cultivator in July and August after the first crop of hay had been removed decreased the infestation of quackgrass more than any other treatment used. The data in Table 2 show that an average of 99.7% control was achieved by this method. This treatment was significantly better than the other treatments at the 1%

Table 2. Reductions in quackgrass infestations following cultural treatment using two methods of estimation.

Treatment	No fertilizer		200 lbs. ammonium nitrate		600 lbs. ammonium nitrate		Average	
	Rhizome length	Quadrats† infested	Rhizome length	Quadrats† infested	Rhizome length	Quadrats† infested	Rhizome length	Quadrats† infested
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Cultivation	99.7	89.0	99.7	89.0	99.8	88.0	99.7	88.9
Plowing and disking	70.1	19.0	84.0	38.0	88.3	49.0	81.5	35.3
Sunflowers	57.0	1.0	61.6	1.5	75.7	8.5	64.9	3.3
Oats	54.7	0.0	55.8	0.5	71.6	8.5	60.7	3.0
Average	70.4	27.3	75.3	32.3	83.9	38.5	76.7	32.6

†Fifty one-foot square quadrats per plot.

level. The control obtained in plots subjected to plowing and disking was significantly better than in plots planted to sunflowers or to oats. There was no significant difference in control between plots planted to sunflowers and those planted to oats. The Russian Mammoth variety of sunflowers did not thrive as expected when planted in the closely spaced rows. It is normally planted in wide rows and cultivated.

The application of nitrogen fertilizer appeared to have relatively unimportant effects on the quackgrass control obtained in this experiment. There were no differences due to fertilizer application in plots cultivated with the field cultivator. Both the 200 lb. and the 600 lb. applications of ammonium nitrate gave moderate increases in control in plots subjected to plowing and disking. The latter had a measureable effect in increasing the control in the plots planted to sunflowers or oats.

The data in Table 2 show most clearly the differences obtained in quackgrass infestations between the two methods of estimation which were used. The rhizome length determinations show a much greater degree of control of the quackgrass than do the infested quadrat determinations. This disparity is greatest in the treatments that gave the lesser degree of control. Planting oats and sunflowers on unfertilized plots reduced the quantity of quackgrass rhizomes in the soil from 55 to 60% but these reductions are not reflected in a decrease of quadrats infested.

DISCUSSION

A review of weather records shows that rainfall was normal in the Ashland area in 1947 with the exceptions of April when the total precipitation was 2.20 inches above normal, and July when the total precipitation of 1.57 inches was 2.20 inches below normal. The major portion of the rainfall in July was received during the later part of the month. Since the cultivation practices did not start until July 12, the effect of the reduced amounts of rainfall in July probably did not have as great an effect as might be supposed. The degree of control obtained in this study does not, therefore, appear to be due to unusually favorable weather conditions. It should be pointed out that in seasons when frequent rainfall is the rule the field cultivator may be of doubtful value in eradicating quackgrass. Quackgrass rhizomes which are exposed will probably not be desiccated sufficiently to be killed because of high moisture conditions. Furthermore, frequent cultivation when wet, of the heavy red clay soils prevalent in the Ashland area, results in rapid deterioration of the physical characteristics of the soil so that they are not likely to be capable of maximum productivity the succeeding year. However, cultivation at intervals of one week or less during dry periods in July and August are not destructive to the soil structure and practical control of quackgrass can be obtained by proper cultivation during this period. A supplementary study on a field scale in 1948 and 1949 has shown that a series of successive cultivations during the drier months

of July and August after the first cutting of hay has been successful in controlling quackgrass.

Plowing and disking to remove top growth was shown in this study to be much less successful in the control of quackgrass. The organic reserves of the quackgrass were not reduced sufficiently during the relatively short period of tillage to cause widespread death of the quackgrass rhizomes. The application of nitrogen fertilizer increased the value of this treatment. However, even with the use of nitrogen, control was inferior to that obtained by the use of the field cultivator.

The use of sunflowers as a smother crop was not particularly successful in this experiment for the growth was not dense enough to shade the ground completely and to prevent the accumulation of organic reserves by the quackgrass. The usual practice of planting oats on quackgrass infested fields resulted in some reduction in the quackgrass infestation. The reduction was not great enough, however, to prevent the quackgrass from continuing to be a serious problem. To be effective as a smother crop, a plant must make sufficient top growth so that complete or nearly complete shading of the soil surface is obtained.

The prevalence of above ground shoots is usually regarded as evidence of a quackgrass infestation. Such observations do not allow exact comparisons of the quackgrass rhizome content in the soil. The use of above ground shoot counts would give a greater degree of accuracy but even here discrepancies exist. The use of shoot development as an estimate of infestation requires that a period of recovery be allowed so that a representative number of shoots will emerge. If the recovery period is too long supplementary growth will appear. If the period is too short maximum development of shoots will not occur. Also, the prevalence of shoots is dependent on the numbers of dormant buds of quackgrass contained in the soil per unit area and the ability of the rhizomes to activate bud growth. The number of buds is related to the length of the contained rhizomes. High levels of nitrogenous and carbohydrate reserves in the rhizome tissues have been shown to promote the development of buds. Therefore, rhizome counts appear to be the better method of estimation.

In this study the determination of rhizome length expresses the extent of infestation more precisely than does the mere determination of the presence of top growth. It is probable that total dry weight of rhizomes per unit area would be a still better estimate of the infestation for dry weights of the rhizomes would be influenced by the length, as well as by the dry matter content of the tissue. Determinations of rhizome length or weight, however, have the disadvantage of being considerably more laborious than methods of estimation suggested in this paper or by others working in the field. This problem is most acute on the less friable soils where the rhizomes must be washed from the soil rather than sorted from it. Even so, estimates of rhizome tissue are likely to be preferable in studies where considerable precision is desired.

SUMMARY

The effectiveness of various methods of eradicating quackgrass was studied. Applications of 0, 200 and 600 lbs. of ammonium nitrate were combined with tillage with a field cultivator, plowing followed by disking, and the use of oats and sunflowers sown as smother crops. The infestations of quackgrass were determined on the basis of rhizome lengths and the prevalence of top growth present before and after these practices were put into effect.

1. The kill of rhizomes was significantly greater where quackgrass was worked with a field cultivator than where other methods were employed.

2. Plowing and disking quackgrass infestations was significantly more effective in reducing the infestation than was planting of sunflowers or oats as smother crops.

3. Quackgrass infestation tended to decrease slightly as the rate of nitrogen application was increased in plots plowed and disked and on plots planted to sunflowers or oats.

4. Working quackgrass sods with a field cultivator after the first hay crop had been removed proved to be a successful method of controlling this weed during 1947, as well as in subsequent field work done in 1948 and 1949. Such a practice is believed to be the most economical and practical measure available for use in the heavy red clay soil of the Ashland area.

5. The measurement of rhizomes appears to be a more exact method of determining quackgrass infestation than the use of infested quadrats but it is more time consuming and not adapted for use on the less friable soil types.

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Techniques and Equipment Used in Evaluating Chemicals for Their Herbicidal Properties

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Introduction

The discovery of the herbicidal properties of 2,4–dichlorophenoxyacetic acid (2, 4–D) created a great impetus in the search for new herbicides. As the herbicidal properties of 2,4–D became more generally known, it was obvious that many closely related chemicals and other organic compounds should be evaluated for their herbicidal properties.

The introduction of the pre-emergence method of controlling weeds in this country (2) involved an entirely new concept of weed control. It was soon apparent that many chemicals may be extremely efficient as pre-emergence herbicides while the same chemicals show little or no phytotoxicity when applied to the foliage of plants. This property of certain compounds to produce different responses when applied as pre-emergence and post-emergence treatments may be indicated by the failure of foliar techniques to detect pre-emergence herbicidal responses of certain compounds. The classical Avena-coleoptile test (17), the single-droplet water test on kidney bean (9), localized applications as smears, or pellets, or in lanolin (3), the pot soil treatment method (6), the split stem technique (8), the plant injection method (11), thread methods of introducing chemicals into plants (5, 12), the single-droplet oil test (16), the leaf immersion technique (7), the leaf-repression method (4) and the cucumber test (10) have been used extensively for studying phytotoxicity, formative effects, and translocation and absorption of plant growth-regulating chemicals. It is generally assumed that growth-regulators are effective by virtue of some chemical reaction which they catalyze or in which they participate. The tests cited above were designed primarily to measure the effectiveness of chemicals as growth-regulators.

The value of the tests cited above for evaluating the phytotoxicity of growth-regulating chemicals has been demonstrated many times. The limitations of using only growth-regulator screening techniques in a herbicide evaluation program can also be clearly demonstrated by conducting the tests using some of the newer chemicals. Several of the most promising herbicides may escape detection after having been screened through several of the tests cited. Recently, field screening techniques have been reported (1, 13, 14, 15) which were designed to evaluate chemicals for their herbicidal properties.

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[2]Drawings and photographs of the equipment discussed are available upon request from the authors.

In a program of herbicide evaluation, screening techniques designed to measure an overall activity are needed. This activity may be the result of such factors as penetrability of the compound into the plant when applied either as pre- or post-emergence treatments, solubility in the plant fluids or protoplasm, transportability of the substance within the plant, rate of inactivation of the material in the soil or in the plant, the type of germination exhibited by the plant and the genetic constitution of the plant. One of the most important essentials required of a herbicide evaluation technique is that it must indicate, from the beginning, the high degree of tolerance or susceptibility exhibited by various crop and weed species to a single chemical.

The techniques described herein are designed to measure overall activity and species response to chemicals of unknown phytotoxicity, when applied as pre-emergence sprays in the primary screening phase under greenhouse conditions and as pre- and post-emergence sprays in the secondary screening phase under field conditions.

MATERIALS AND METHODS

The quantity of compounds available from most sources requires that the initial screening technique be designed to use effectively very small amounts of chemical. The smaller the amount of chemical required in a test the greater the number of compounds that can be evaluated. All rates of application discussed hereafter are stated in terms of chemically pure compounds.

The micro screening technique used for detecting herbicidal properties of a compound required 184 mg. of the material. Test crop plants includes corn *(Zea mays)* hybrid US13, wheat *(Triticum vulgare)* variety Thorne, cotton *(Gossypium hirsutum)* variety Delta pine 15, and soybeans *(Soja max)* variety Hawkeye. Test plants considered as weeds are crabgrass *(Digitaria sanguinalis)*, mustard *(Brassica kaber)*, rough pigweed *(Amaranthus retroflexus)* and annual ryegrass *(Lolium multiflorum)*. Each crop plant is seeded separately in a four-inch one quart oil can. The four weed species are seeded uniformly with each crop at the rate of 20 weed seeds of each species.

Each chemical is applied as a pre-emergence spray at rates of 2 and 16 pounds per acre immediately after planting. Each container receiving the 2 pound rate require 1.7 mg. of chemical, and those receiving 16 pounds per acre require 13.6 mg. of chemical. The experimental design used was a randomized split-plot with 3 replications. The chemicals are applied using an atomizer[3] (figure 1). Two ml. of the spray mixture are applied to each container, making the volume equal to 264 gallons per acre. A small glass vial 10 x 75 mm. containing 2 ml. of spray material is inserted in the atomizer. The spray material is forced out of the atomizer at a pressure of 5 p.s.i. The entire apparatus is enclosed to reduce spray drift

[3]De Vilbiss atomizer 152.

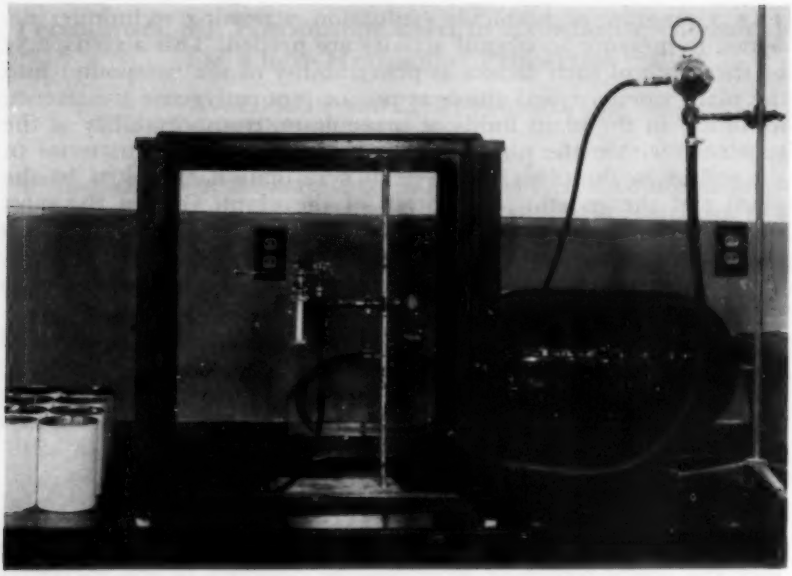

FIG. 1. Apparatus for the application of chemical sprays in the micro-screening technique. Small glass vial containing white liquid in atomizer bottle is discarded after each operation to reduce chance of contamination.

and to prevent the spray from coming in contact with the operator (figure 1).

The macro-screening technique used for detecting herbicidal properties of a compound require 8.1 grams of the material. Corn, wheat, cotton, soybeans, ryegrass, crabgrass, mustard, and rough pigweed are used as test plants. Metal flats, 14″ x 20″, stamped from galvanized sheet metal, are used for growing the test plants. The crop plants are seeded in single opened rows as follows: corn 15 seeds, wheat 40 seeds, cotton 30 seeds and soybeans 15 seeds per row. Each crop is seeded at a depth of 1¼ inches. This depth is obtained by covering the seeds with five quarts of soil. The weeds are seeded on a volume basis as follows: mustard 3 cc., pigweed 1 cc., ryegrass 4 cc., and crabgrass 3 cc. per flat. The weed seeds are distributed uniformly over the entire surface of the flat and covered with two quarts of soil to a depth of ¼ inch (figure 2).

Each chemical is applied as a pre-emergence spray at rates of 2 and 16 pounds per acre immediately after planting. The experimental design is a randomized plot with 3 replications. The chemicals are applied using an experimental screening table with an endless conveyor belt to transport the seeded flats under the spray nozzles. A speed of 2 m.p.h. and a pressure of 30 p.s.i. are maintained. Using these constants, the table is calibrated to apply each chemical in 40 gallons of water per acre.

Table 1. The response of eight plant species to several herbicides applied as pre-emergence sprays in the macro-screening technique.

Crop and weed plants	Chemicals and rates in lbs. per acre										
	IPC†			CIPC‡			A-DNOSBP§			CMU**	24D††
	2	8	16	2	8	16	2	8	16	2	1
Crops											
Cotton											
Injury rating*	0	0	0	1	0	3	1	0	1	1	2
Height reduction, per cent	0	19	0	0	0	23	2	0	0	8	4
Plants killed, per cent	3	28	6	6	12	23	30	26	3	0	0
Soybeans											
Injury rating*	0	0	2	2	4	7	1	0	2	1	3
Height reduction, per cent	4	7	9	25	32	44	11	0	21	12	27
Plants killed, per cent	0	23	15	0	0	0	0	2	0	0	5
Corn											
Injury rating*	0	0	1	2	2	3	0	0	3	1	3
Height reduction, per cent	3	15	3	4	3	23	0	0	8	3	16
Plants killed, per cent	0	11	0	21	2	0	0	0	2	0	0
Wheat											
Injury rating*	1	1	1	1	4	6	0	1	4	0	2
Height reduction, per cent	0	2	0	0	2	6	0	0	3	6	10
Plants killed, per cent	8	7	17	30	22	38	13	17	40	3	2
Weeds											
Mustard											
Injury rating*	0	4	5	9	9	9	9	10	10	7	4
Plants killed, per cent	0	30	53	90	87	97	97	100	100	88	47
Pigweed											
Injury rating*	0	3	2	6	9	9	6	10	10	9	9
Plants killed, per cent	0	23	33	42	85	97	61	100	100	99	95
Ryegrass											
Injury rating*	7	9	9	9	9	9	5	9	10	7	9
Plants killed, per cent	73	97	98	93	95	98	33	93	100	80	95
Crabgrass											
Injury rating*	1	1	3	9	9	10	2	9	9	2	7
Plants killed, per cent	0	10	17	47	98	100	13	93	97	80	40

*Injury rating: 0, none; 1–3, slight; 4–6, moderate; 7–9, severe; 10, all killed.
†Isopropyl N-phenyl carbamate.
‡Isopropyl N- (3-chlorophenyl) carbamate.
§Alkanolamine salt of dinitro-ortho-secondary-butyl-phenol.
**3-(p-chlorophenyl) –1,1-dimethylurea.
††Alkanolamine salt of 2,4-D.

The essential features of the screening table (figure 3) include an endless flexible steel conveyor belt 24 inches by 12 feet, a variable speed automatic transmission, a ¾ h.p. electric motor, a spray boom adjustable for height and nozzle spacing, an automobile speedometer, a pressure regulator, an air compressor, a mercoid magnetic positive quick-acting shutoff valve, ball bearing rollers at the entrance and exit ends of the table, solution tanks, and an operator's panel including speed, pressure, and spray control. To facilitate the application of small amounts of chemical, to reduce contamination, and to permit rapid change of compounds, the solution container shown in figure 4 was developed. An automobile speedometer is used to indicate speed of travel. The speedometer ratio is reduced so that a dial reading of 10 m.p.h. is equivalent to 1 m.p.h., etc. The automatic variable speed transmission enables the operator to de-

FIG. 2. Metal flats, aluminum left and galvanized right, indicating the method of seeding in the macro-screening technique. Left, check and right, chemical has controlled weeds and inhibited growth of dicot crop species.

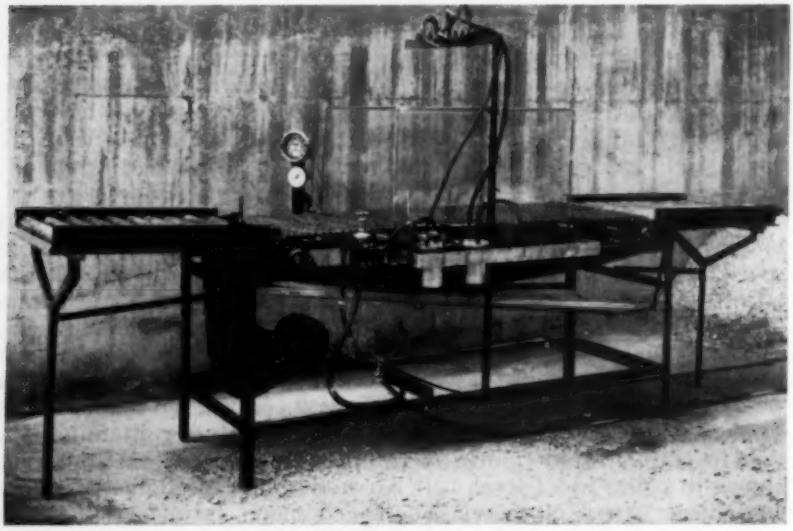

FIG. 3. Apparatus for the application of chemicals in the macro-screening technique.

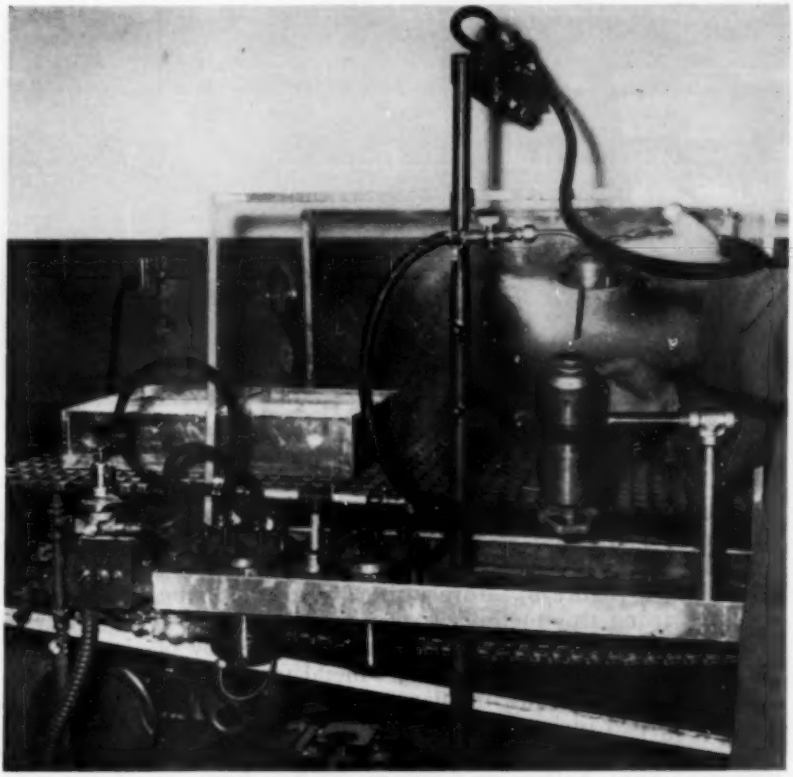

FIG. 4. Adapter for enclosing the chemical container. Standard aerosols are used as chemical containers and are discarded after use to reduce the chance of contamination.

crease or increase the rate of application by changing the speed of the conveyor belt. The number of controlled variables makes it possible to deliver a series of rates of chemical per acre without changing the solution. This is justified only in pre-emergence applications where gallonage is relatively unimportant if complete uniform coverage is obtained. Standard aerosol cans are used as solution containers for screening operations (figure 4). The aerosol containers are relatively inexpensive and may be discarded after each application in order to reduce the chance of contamination. Each chemical is applied from a new container.

Numerous calibrations have indicated the efficiency of the screening table. One chemical at one rate per acre, replicated 5 times, may be applied in 11 seconds. The volume delivery from 2 flat fan type nozzles[4] spaced 10 inches apart is consistently 200 ml. ± 1.0 ml. in 5

[4]Tee Jet Nozzles 730308.

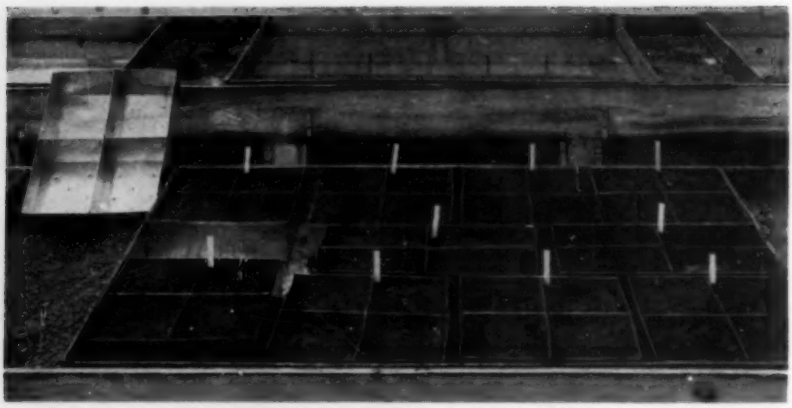

FIG. 5. Sub-irrigation pans. Perforated metal flats are sprayed pre-emergence and placed in the pans where they are watered.

seconds, when the table is operated at 2 m.p.h., and a pressure of 30 p.s.i. is maintained.

In the micro and macro screening techniques, all test plants are sub-irrigated (figure 5). More uniform growth of the test plants is obtained using this method of watering as compared to overhead surface watering. Sub-irrigation is accomplished by placing 11 flats, 14″ x 20″, in each galvanized sheet metal tank, 60″ x 57″ x 4″. Immediately after spraying, the flats were placed in the irrigation tanks containing two inches of water. As soon as the soil surface in the flats becomes uniformly moist, the water is drained from the sub-irrigation pans. Following drainage, all flats have a uniform moisture content of field capacity. This method of watering has facilitated uniform germination of crop and weed seeds. Subsequent sub-irrigations are practiced as needed and no surface water is applied.

The "soil" used in the micro and macro screening techniques is a composted greenhouse potting soil consisting of two-thirds loam and one-third sand. An attempt was made to keep the composted soil as uniform as possible.

The field plot screening technique used for herbicide evaluation requires 250 grams of each chemical. Thirty-four test plants and weeds (table 2) are used in the field screening technique. A field 140′ x 450′ is required to conduct the screening test. Each crop is seeded in two rows spaced 20 inches apart 450 feet long. Each crop is sown at a standard seeding rate using a calibrated hand seeder. German millet and rape are seeded uniformly over the area to serve as weeds in addition to the "normal" weed population.

Each chemical is applied as a pre-emergence spray at rates of 2 and 16 pounds per acre immediately after planting. The chemicals are also applied as post-emergence sprays at 2 and 16 pounds per acre when soybeans reach the first trifoliate leaf stage. The two rates chosen for the field screening test were arbitrary only if the chemicals

Table 2. The effect of an alkanolamine salt of dinitro ortho secondary butyl phenol on crops and weeds when applied as pre- and post-emergence sprays.

Crops	Pre-emergence				Post-emergence			
	4 pounds per acre		16 pounds per acre		2 pounds per acre		4 pounds per acre	
	Vigor scale*	Plants killed	Vigor scale*	Plants killed	Vigor scale*	Plants killed	Vigor scale*	Plants killed
	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
Corn	0	0	5	95	2	0	2	0
Wheat	3	10	10	100	1	0	2	0
Sorghum	0	0	7	90	3	0	4	0
Oats (spring)	2	10	8	80	0	0	0	0
Oats (winter)	0	0	10	100	2	0	4	0
Barley	4	30	10	100	0	0	0	0
Rye	5	50	10	100	0	0	0	0
Ladino clover	4	60	10	100	0	0	3	0
Sudan grass	4	15	9	40	1	0	3	0
Alfalfa	3	60	10	100	0	0	3	0
Orchard grass	10	100	10	100	0	0	0	0
Red clover	3	40	10	100	0	0	3	30
Crimson clover	2	60	10	100	0	0	4	70
Soybeans	0	0	8	40	0	0	4	0
Millet, German	2	50	10	100	1	0	2	0
Vetch	0	10	8	95	0	0	0	0
Soybeans	0	0	6	20	2	0	3	0
Pea, Austrian Winter	0	0	3	20	0	0	0	0
Birdsfoot trefoil	10	100	10	100	2	10	4	15
Korean lespedza	0	50	10	100	0	0	3	0
Sericea lespedza	4	40	10	100	0	0	0	0
Lima beans (large)	2	20	2	20	2	0	4	0
Snap beans	0	0	0	0	3	0	3	0
Rape	10	100	10	100	10	100	10	100
Cantaloupe	2	0	10	100	1	0	9	90
Watermelon	0	0	0	0	4	0	8	90
Squash	0	0	6	80	6	0	10	100
Cucumber	0	0	10	100	10	100	10	100
Lima beans (small)	0	10	6	90	4	0	5	0
Cotton	0	0	1	5	2	0	4	0
Sugar beets	10	100	10	100	10	100	10	100
Flax	5	30	10	100	2	0	8	20
Peanuts	0	0	0	0	1	0	3	0
Buckwheat	10	100	10	100	10	100	10	100
Weeds								
Broadleaf weeds	10	100	10	100	10	100	10	100
Grass weeds	5	70	10	100	1	10	3	20
Toxicity rating average	3.2	34.0	7.8	77.1	2.6	14.9	4.3	26.7

*See Table 1 for explanation of scale.

have not been evaluated in the micro- and macro- techniques (table 3). The rates of chemicals used in the field screening program are normally based on results obtained from the micro- and macro-screening tests conducted in the greenhouse.

The chemicals are applied at right angles to the crops (figure 6). Each chemical treatment is 5 feet wide and long enough to extend across all test plants. Each individual plot consists of two rows spaced 20 inches apart five feet long. In a field area 140′ x 450′, 20 chemicals can be evaluated including 10 checks for comparison. Five of the check plots remain untreated while five are maintained weed free. A field screening technique of this design contains 3,200 treated plots and 400 check plots.

All chemicals are applied with an experimental plot sprayer (figure 7) at 40 gallons of spray material per acre. The sprayer is

Table 3. The effect of sodium 2,4–dichlorophenoxyethyl sulfate on crops and weeds when applied as pre- and post-emergence sprays.

Crops	Pre-emergence				Post-emergence			
	3 pounds per acre		6 pounds per acre		3 pounds per acre		6 pounds per acre	
	Vigor scale*	Plants killed	Vigor scale*	Plants killed	Vigor scale*	Plants killed	Vigor scale*	Plants killed
	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
Corn	2	0	6	100	0	0	0	0
Wheat	9	95	10	100	0	0	0	0
Sorghum	9	90	9	95	0	0	3	0
Oats (spring)	8	85	9	95	0	0	0	0
Oats (winter)	8	85	9	95	2	0	3	0
Barley	7	50	8	70	0	0	0	0
Rye	5	50	9	90	0	0	0	0
Ladino clover	10	100	10	100	5	20	5	20
Sudan grass	10	100	10	100	0	0	3	0
Alfalfa	10	100	10	100	2	0	2	0
Orchard grass	10	100	10	100	2	0	2	0
Red clover	10	100	10	100	2	0	3	0
Crimson clover	10	100	10	100	2	0	3	0
Soybeans	9	95	10	100	2	0	4	0
Millet, German	10	100	10	100	0	0	0	0
Vetch	10	100	10	100	1	0	2	0
Soybeans	8	80	10	100	2	0	4	0
Pea, Austrian Winter	8	80	9	95	1	0	2	0
Birdsfoot trefoil	10	100	10	100	0	0	0	0
Korean lespedeza	10	100	10	100	1	0	3	0
Sericea lespedza	10	100	10	100	1	0	3	0
Lima beans (large)	10	100	10	100	2	0	4	0
Snap beans	10	100	10	100	3	0	4	0
Rape	10	100	10	100	0	0	0	0
Cantaloupe	10	100	10	100	6	0	7	0
Watermelon	10	100	10	100	4	0	7	10
Squash	10	100	10	100	4	0	5	0
Cucumber	10	100	10	100	1	0	3	0
Lima beans (small)	10	100	10	100	0	0	3	0
Cotton	10	100	10	100	3	0	4	0
Sugar beets	10	100	10	100	1	0	2	0
Flax	10	100	10	100	1	0	3	0
Peanuts	8	80	9	95	1	0	2	0
Buckwheat	9	95	10	100	0	0	3	0
Weeds								
Broadleaf weeds	10	100	10	100	0	0	5	0
Grass weeds	10	100	10	100	1	0	2	0
Toxicity rating average	9.2	91.3	9.7	98.2	1.4	0.6	2.8	0.8

*See Table 1 for explanation of scale.

calibrated to deliver this volume when operated at 2 m.p.h. and 30 p.s.i. is maintained. The experimental sprayer embodies the essentials necessary for the application of experimental chemicals — liquid under pressure, a pressure reducing valve, pressure gauges, filters and nozzles. These features along with compressed air storage for pressure, facilities for two or more containers of liquid, two booms, a boom shield, geared up speedometer, quick-acting shutoff valves, efficient facilities for changing solutions, and light weight overall make it especially adaptable to the requirements of field screening techniques. The most important element of the equipment is accuracy of application and distribution.

Discussion and Results

The micro-, macro-, and field-screening techniques discussed are designed to evaluate the herbicidal properties of compounds of un-

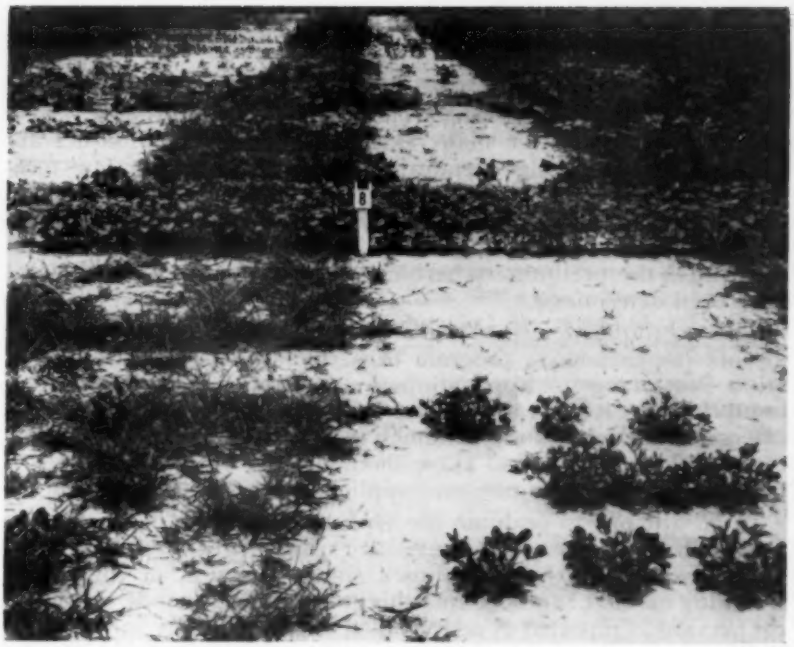

FIG. 6. Field screening technique. Left an untreated check, and right, a chemical applied pre-emergence which has controlled weeds causing little injury to cotton and peanuts, but serious injury to squash, soybeans and other crops in background.

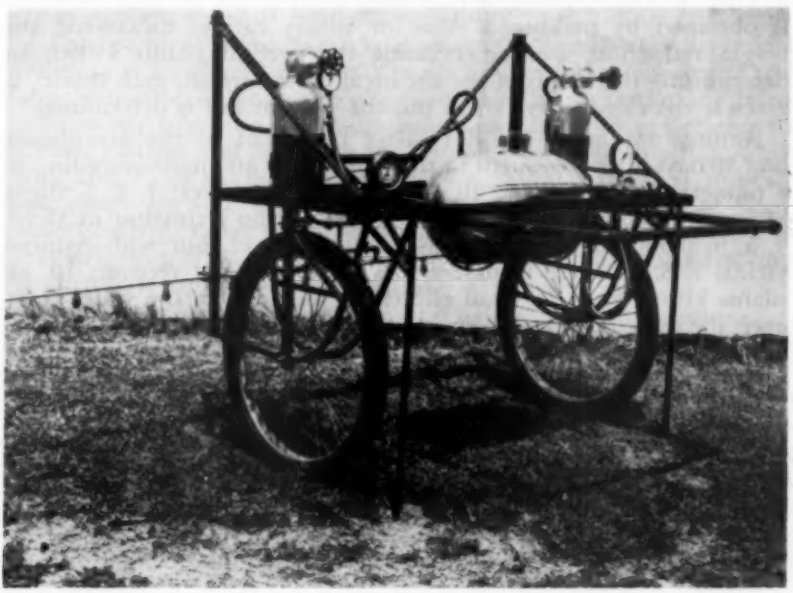

FIG. 7. Experimental field plot sprayer used for the application of chemicals in the field screening technique.

known phytotoxicity. The need for such a series of primary and secondary herbicide screening techniques is evident from a review of the literature. While many excellent screening techniques are available for screening chemicals as growth-regulators, few techniques have been suggested for detecting and evaluating herbicides. The herbicide screening techniques that appear in the literature are largely adapted to secondary screening or to that phase of evaluation after the preliminary herbicidal properties of the compound have been determined.

The techniques described in this paper are an attempt to approach a more comprehensive program of herbicide detection and evaluation. Post-emergence applications are made only in the field screening technique. Results to date show that the micro- and macro- pre-emergence techniques are extremely sensitive and will readily indicate herbicidal responses. These methods also furnish data needed for the pre- and post-emergence applications in the field technique.

In an attempt to evaluate the sensitivity of these methods, over 1000 compounds, screened previously using growth-regulator techniques, were re-evaluated using a slight variation of the micro-screening method.[5] In screening this group of compounds, no chemical previously reported as active failed to show activity in the micro test. However, a number of compounds that were relatively inactive when screened using foliar techniques have been found to show herbicidal properties as pre-emergence sprays in the micro-test.

Typical data obtained from the micro- and macro-tests are shown in table 1. The response of each crop to each rate of each chemical is obtained by making a vigor or injury rating, measuring the height reduction, and determining the percent plants killed. In determining the effects of the chemical on the weeds, each species is given a vigor or injury rating and the percent kill is determined.

Ratings are made ten days after treatment in the greenhouse and 30 days after treatment in the field. They are made according to a numerical scale of 0 to 10 as follows: 0, no effect; 1, 2, 3, slight injury, plants usually recover with little or no reduction in yield; 4, 5, 6, moderate injury, plants usually recover, but with reduced yields; 7, 8, 9, severe injury, plants usually do not recover; 10, all plants killed. Five classes of effects are included in the scale. However, the three classes of injury are weighted so that in each class the lower the rating in the range the lower the degree of injury. Height reduction is determined by measuring the height in inches of the test plants and the results are expressed as a percentage of the untreated checks. The percent plants killed is determined by counting the number of plants emerged and expressing the result as a percentage kill when compared with an untreated check (table 1).

The micro screening technique requires 184 mg., the macro technique 8.1 grams, and the field screening technique 250 grams or a

[5]These compounds were screened in cooperation with Dr. J. W. Mitchell, Basic Growth Studies, BPIS&AE.

total of 259 grams of chemical for the evaluation program. Only those compounds showing definite herbicidal properties in the micro- and macro-screening techniques are included in the field screening technique. Therefore 9 grams of a chemical are sufficient to complete the primary or greenhouse screening phases of the evaluation program. When the quantity of chemical is very limited, the micro screening technique can be conducted without replication with a total of 30 mg. of chemical. The results from this technique will indicate the response of 4 crop species and 4 weed species at dosage levels of 2 and 16 pounds of the chemical per acre.

In formulating chemically pure compounds for application, various organic solvents are used depending upon the solubility of the compound. One advantage of pre-emergence screening techniques is that relatively high concentrations of organic solvents can be used to formulate the compounds with little or no effect of the solvent on the plant species. The following organic solvents were evaluated as 5 percent (by volume) aqueous mixtures at a total volume of 40 gallons per acre for their effects on the test plants when applied as pre-emergence sprays: methyl, ethyl, isopropyl, isobutyl and isoamyl alcohol and xylene, acetone and toluene. These solvents produced no effects on the test plants. In addition to the use of solvents, two percent of the spray mixture consists of a wetting agent[6] which is added to improve the dispersion of the chemical. With insoluble or only very slightly soluble compounds the spray mixture is transferred to a Waring Blendor after the addition of the wetting agent. Homogenizing for 5 to 10 seconds produces a suspension of very fine particles easily applied by each spraying technique.

The test plants were chosen to represent monocots and dicots with different types of germination. Results to date indicate that the type of germination exhibited by the plant may be an important factor influencing tolerance or susceptibility of plants to pre-emergence sprays. Cotton and soybeans exhibit epigeous germination, while corn and wheat exhibit hypogeous germination. Crabgrass, mustard and rough pigweed are used because of their importance as weeds and their wide range of adaptation. Annual ryegrass is used because it is well adapted to greenhouse growth and has exhibited a response to chemicals unlike that of crabgrass.

Typical results obtained from the field screening technique are shown in tables 2 and 3. The high degree of plant specificity exhibited in the data indicates the necessity of using a large number of test plants in order to evaluate chemicals accurately and efficiently for their herbicidal properties. It is equally evident that foliar techniques alone are inadequate and a pre-emergence technique of some type is essential in the primary screening phases of a herbicide evaluation program. The herbicidal properties of a compound such as sodium 2,4–dichlorophenoxyethyl sulfate (table 3) would escape detection using foliar screening techniques. Using pre-emergence

[6]Tween 20, a nonionic wetting agent, supplied by the Atlas Powder Company, Wilmington, Delaware.

techniques, the activity of this compound is readily evident. A number of other compounds are known to exhibit activity of this type. The toxicity rating averages shown at the bottom of tables 2 and 3 permit valid comparisons to detect small differences between closely related compounds.

Results obtained in the micro and macro screening techniques under greenhouse conditions have been highly reproducible and highly correlated with results obtained under field conditions.

SUMMARY

Three techniques and application equipment used to evaluate chemicals for their herbicidal properties are discussed.

1. The micro screening technique required 184 mg. of chemical, the macro technique 8.1 grams for a total of less than 9 grams of a chemical for the primary or greenhouse screening program. The field screening program required 250 grams making a total of 259 grams required for the primary and secondary screening programs.

2. The three evaluation techniques involved the response of eight species to each chemical at 2 and 16 pounds per acre applied as pre-emergence sprays in the primary screening phase under greenhouse conditions and the response of 35 plant species to each chemical at 2 and 16 pounds per acre applied as pre and post-emergence sprays in the secondary screening phase under field conditions.

3. The techniques discussed were designed to use small quantities of compounds to detect effectively a wide range of tolerance and susceptibility of crop and weed species to the chemicals in the initial or primary screening phases.

4. The application equipment discussed was designed to obtain a high degree of efficiency, to permit rapid application of chemicals and rapid change from one chemical to another, to apply chemicals uniformly and accurately, and to maintain a high degree of reproducibility of results. In designing the equipment every effort was made to develop equipment that would apply chemicals similar to the type of application desired under practical field conditions.

5. A large number of compounds, previously screened using several different techniques, were re-evaluated to determine the validity and sensitivity of the micro, macro and field screening techniques. Results of these investigations indicated that the techniques described were highly sensitive and that a high degree of correlation existed between the results obtained in the primary screening phase under greenhouse conditions and the secondary screening phase under field conditions.

6. Results were presented which show that complete-coverage foliage sprays often failed to detect herbicidal properties of known established herbicides. These studies also suggested the need for at least one pre-emergence screening technique, or a screening technique that will furnish comparable information, in the primary screening program.

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Aromatic Solvents for the Control of the Submersed Water Weed Naiad, Najas guadalupensis (Spreng.) Morong., in South Florida [1, 3]

By Charles C. Seale, John W. Randolph and John C. Stephens[2]

Many different types of water weeds are found infesting the drainage and irrigation systems in south Florida, where a subtropical climate is very favorable for rapid growth.

Water hyacinth, *Eichhornia crassipes* Solms., was the most serious pest in the Everglades region until 1946, but was brought under control on an extensive scale by treatment with 2,4–D (7, 9, 11).

Dense growths of naiad, *Najas guadalupensis* (Spreng.) Morong., and other submersed water weeds are commonly found in this area and appear to have become more prevalent since the large-scale removal of the water hyacinth (12).

These submersed growths retard the flow of water in drainage systems to a greater extent than water hyacinths, and consequently must be kept under control for the proper practice of soil conservation and water control measures (3). In south Florida, where the terrain is flat and rainfall is high, crop and livestock production are affected adversely when water control facilities are impaired by an undesirable growth of water weeds.

The submersed weed naiad roots at the bottom of the drainage canals and produces long flotant strands of dense growth. Under such conditions the movement of water is generally confined to an area just under the surface as a sinuous current meandering along the top of this flotant mass.

Flow measurements on established courses on drainage systems in south Florida made by the Soil Conservation Service, U. S. Department of Agriculture, show that this type of aquatic vegetation is the worst yet studied in reducing the capacity of drainage canals (1). In a farm lateral ten feet wide and five feet deep, which became infested with naiad during the summer of 1949, it was found that the retardance coefficient "n" in the Manning Formula increased from a value of approximately 0.040 to 0.680 in a period of about ten weeks. In July 1950 an arterial canal about fifty feet wide and ten feet deep was almost completely choked by a dense growth of naiad. Flow measurements in this case showed the value of the Manning coefficient to be 1.183, the highest value yet encountered in these studies. Canals in this area are generally designed for a retardance

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[1]Contribution from The Florida Everglades Agricultural Experiment Station in cooperation with the Soil Conservation Service, U. S. Department of Agriculture and the Central and Southern Florida Flood Control District. Published with the approval of the Director, Florida Agricultural Experiment Station and the Chief, S.C.S., U.S.D.A.

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[3]Florida Agricultural Experiment Station Journal Series, No. 76.

coefficient of about 0.035 and the reason for the failure of drainage systems clogged with heavy growths of submersed water weeds is very apparent.

During the winter season or sometimes during excessively high autumn flows, large masses of this weed break loose and float downstream, causing obstructions at bridge piers and clogging pump intakes. These conditions cause further difficulties in water control.

METHODS OF CONTROL

Mechanical methods for the control of submersed water weeds have been widely practiced in many places where they occur as pests (4). In south Florida chain dragging of the channel is the most common mechanical method for the removal of naiad. However, the rooted portion of the plant is little affected and very rapid regrowth occurs. Dredging at periodic intervals with a dragline is sometimes practiced for more complete ditch cleaning and maintenance. This method has the disadvantage of being very expensive and regrowth of the plant still takes place at a comparatively fast rate.

Chemical methods for the control of submersed water weeds show promise of being more effective and less expensive. Chlorinated benzene products have been used with success, but a more recent advancement is the use of aromatic solvents for the control of naiad and many other submersed aquatic plants (4, 6, 10). The characteristics of the aromatic solvents of petroleum and coal tar origin which are most suitable for this type of weed control have been outlined in several reports (2, 4, 5, 8, 10).

GREENHOUSE STUDIES

In 1948 greenhouse studies were initiated by Seale (12) to evaluate the effects of several different herbicides on naiad grown in glass containers in the greenhouse of the Everglades Experiment Station. The herbicidal treatments were injected under water by means of a graduated hypodermic syringe. This procedure provided a simple means of applying accurately small measured quantities of the herbicides and satisfied the requirement that they should be applied under water. This method permits a large number of herbicides to be screened rapidly. The more promising types can then be included in larger scale field tests. Results of these and other small scale tests indicated that certain aromatic petroleum solvents might be expected to control the submersed water weed naiad. This finding was confirmed later in field tests.

FIELD STUDIES

In May 1950 a field test was run with three aromatic solvents, WS1492, WS1494 and WS1495, on a lateral ditch heavily infested with naiad in an orange grove west of Ft. Lauderdale (Fig. 1). Characteristics of these three aromatic solvents are given in Table 1.

Herbicidal treatments were applied at concentrations ranging from about 200 to 500 ppm to plots marked out on the lateral. The

FIG. 1. Dense growth of the submersed water weed naiad, *Najas guadalupensis* (Spreng.) Morong, in a canal near Ft. Lauderdale, Florida before treatment.

plots were 150 feet in length and ten feet in width and were separated by untreated guards fifty feet in length. Prior to treatment the water in the lateral was pumped down to a depth of 1 to 1½ feet in order to obtain relatively concentrated and thus more efficient applications of the herbicides. This depth provided sufficient draft for a flat bottomed boat used in the test. Sluice gates were closed after lowering the water level, essentially stopping flow. Treatments were applied by means of a spray unit consisting of a gear pump driven by a ¾ h.p. gasoline motor operated from the boat. Spray materials were injected under water through Monarch No. 67 nozzles spaced one foot apart on extension leads from a boom assembly

Table 1. Characteristics of certain aromatic solvents.*

	WS 1492	WS 1494	WS 1495
	ASTM, Distillation °F		
Initial boiling point	281	302	406
50 per cent point	287	426	504
95 per cent point	335	532	566
Final boiling point	344	550	580
Sp. grav. @ 20/20 °C.	0.8721	0.9031	0.8696
Mixed Aniline Point, °F	51	81	135
Flash Point	90	140	190
Per cent aromatics	99.5	77	35

*Experimental samples of these materials were supplied gratis by the Esso Laboratories, Standard Oil Company, Elizabeth, N. J.

FIG. 2. A clear channel after treating naiad, *Najas guadalupensis* (Spreng.) Morong., with the aromatic solvent WS1492 at 275 ppm.

at an operating pressure of about forty pounds per square inch. Water was pumped back into the lateral to a normal level of three to four feet about 48 hours after treatment. Slope courses had been laid out previously on laterals in this area in order to establish values of the retardance coefficient "n" under varying conditions of weed growth. Temperature of the water in the lateral at the time of applications of the herbicides was approximately 90° F.

In June 1950 another field test was run to determine the practicability of applying these aromatic solvents on a larger field scale. A lateral ditch located about ½ mile north of the site of the previous experiment was treated with approximately 250 ppm of the spray materials. In this test a small tractor was used to tow the spray boat and the average rate of application was about one mile of ditch per hour.

A mixture of game fish and rough fish (gar and mud fish) were present in the ditch before the tests were made. These weed killers are toxic to fish. However, when the water was lowered prior to treatment the bass and other game fish left the ditches for deeper water while the gar and mud fish remained and were killed. In both tests, several hundred large garfish and a few small minnows were destroyed but no dead game fish were seen. The game fish subsequently returned when the weeds had decomposed (Fig. 2) and the water was returned to normal levels.

DISCUSSION

Combined results of both field tests indicate that the aromatic solvent WS 1492 applied at the rate of about 250–350 ppm in the manner outlined gave a satisfactory control of the submersed water weed naiad. The dense growth sank to the bottom of the ditch and commenced disintegrating a short time after treatment, thus permitting a free movement of water in an open channel. Two weeks after spraying, approximately 95 percent of the plants were dead and two months later there was little evidence of regrowth. It is estimated that a ditch properly treated with WS 1492 will remain comparatively free from extensive regrowth of naiad for a period of three to four months.

The herbicidal effects of WS 1494 were very much less pronounced. The mortality rate was lower and affected plants tended to rise to the surface of the ditch instead of sinking to the bottom; also disintegration was slower. Treatments with WS 1495 had very little herbicidal effect. Consequently, WS 1494 and WS 1495 appear to be unsatisfactory for the control of naiad at the rates applied.

The herbicidal effects of the aromatic solvents used in these tests appear to be directly associated with their aromatic content. The best herbicide, WS 1492, contained 99.5 percent aromatics, whereas the less effective solvents, WS 1494 and WS 1495, had aromatic contents of 77 and 35 percent, respectively.

These experiments may provide the key to the control of rough fish and improvements to game fishing within certain ditches where the water can be lowered before application of the herbicide and the game fish can temporarily escape to deeper water. Some herbicides remain to contaminate the water after treatment but WS 1492, after the emulsion breaks within several hours, rises and evaporates, leaving the water relatively unpolluted. This characteristic is highly desirable in treatment of waters where fish and wildlife exist and where there is a danger of crop damage by later using the water for irrigation.

SUMMARY

The submersed water weed naiad, *Najas guadalupensis* (Spreng.) Morong., is commonly found in the irrigation and drainage systems of south Florida and appears to be more prevalent since the large scale removal of the water hyacinth *Eichhornia crassipes* Solms. Flow measurements on established slope courses show that naiad is the worst weed yet studied in reducing the capacity of drainage canals.

Mechanical methods of control have been practiced but are not very satisfactory. Greenhouse studies in 1948 for the rapid evaluation of the effects of several herbicides on naiad grown in glass containers indicated that certain aromatic solvents could be expected to control this weed. In 1950 field tests were carried out with the aromatic solvents WS 1492, WS 1494 and WS 1495 having 99.5, 77, and 35% aromatics respectively. Application concentrations ranged from 200 to 500 ppm. Water in the lateral was pumped down to a

low level prior to treatment and was returned to a normal level 48 hours after application of sprays. Herbicides were applied under water from a spray rig operated from a boat. The aromatic solvent WS 1492 applied at the rate of 250 to 300 ppm gave a satisfactory control of naiad for three to four months. The solvents WS 1494 and WS 1495 gave very poor results. The herbicidal properties of these aromatic solvents appear to be directly associated with their aromatic content, the most herbicidal possessing the highest amount of aromatics.

By lowering the water level in the ditches prior to treatment the game fish temporarily escaped to deeper water while the less desirable garfish remained and were killed by the treatments. The game fish subsequently returned when the solvent had dissipated and the water was restored to normal levels.

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Comments on Thorn Scrub Control with Herbicides in Africa

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THE problem of halting thorn bush encroachment in our Bushveld regions, and the eradication of scrub which has overrun eight million morgen and which in 1948 was responsible for an estimated annual loss in beef amounting to £1,600,000 (1), is still unsolved. If any progress has been made nothing has been published. The most troublesome encroaching species are *Acacia karroo, A. heterocantha, A. detinens, A. robusta, A. arabica* and *Dichrostachys glomerata.*

The exact reason for encroachment is obscure. It has been described as a phenomenon of this century. A stable equilibrium existed between grass and bush prior to 1900, as, up to that time, little or no encroachment seems to have occurred. The periodic fires which swept the country may have been one factor maintaining this balance, by preventing the widespread establishment of young thorn seedlings. This does not mean that firing will destroy the existing bush – this will only give rise to further unwanted coppice growth. The absence of fire, coupled with overgrazing, may be the main cause of bush encroachment. (2)

In the eradication of thorn encroachment two main problems are encountered:–

(1) Control of low growing coppice growth.

(2) Control of relatively clean stemmed trees.

The control of coppice growth is by far the most difficult because the main stem is either non-existent above ground or is inaccessible due to the thorny branches surrounding it. This type of growth needs an overall spray. When dealing with relatively clean and open stemmed trees the problem of approach is much easier. Mechanical removal by means of winches is possible and herbicides can be applied conveniently to the lower trunk and crown.

A mixture of the esters of 2,4–dichlorophenoxyacetic acid and 2,4,5–trichlorophenoxyacetic acid (Brushkiller) was applied to *Acacia heterocantha,* "Haak en steek bos", during Spring, Summer, Autumn and Winter as overall sprays in water and 10% oil emulsion carriers at 1% and 2% concentration and applying 75 gallons solution per acre. No kills were obtained as judged one year after application. Indications are that at least two sprayings are necessary to give a complete kill. Applied in Diesel C.I fuel at 4% concentration to the base of the tree the herbicide showed no improvement over pure Diesel C.I fuel.

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Comments on Cogon and Torpedo Grasses: A Challenge to Weed Workers

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Two aggressive rhizomatous weedy grasses now established in the southeastern United States are a challenge to weed workers. They are cogon grass, *Imperata cylindrica,* from Asia and torpedo grass, *Panicum repens,* from the Mediterranean region.

Cogon grass is regarded as one of the worst weeds in southeast Asia (1) and parts of Africa (2). Probably more than 2,500 acres of it are now established in south Mississippi, Alabama, and throughout Florida. Two points of introduction are known, Grand Bay, Ala. (3), and McNeil, Miss. (4)

The introduction at Grand Bay was accidental. Cogon grass appeared where the grass lining of imported boxes containing bare root satsuma orange plants was discarded in late 1912. It has since spread by accidental transport of rhizomes and natural dispersal of seed over an area 15 to 20 miles from the original site. Cogon grass now covers probably more than 500 acres in this vicinity.

The introduction at McNeil, Miss., was made in the search of a superior forage plant. It was planted at several sites on the experiment station farm. Later experimental plantings were made at Auburn, Ala., Gainesville, Fla., and Brooksville, Fla.

The small plot at Auburn, Ala., has been eradicated by digging out the rhizomes. The experimental areas have been continued at McNeil, Miss., Gainesville, Fla., and Brooksville, Fla.

A few acres have been planted by farmers near McNeil, Miss. Probably the total on the experiment station and farms nearby does not exceed 20 acres.

In Florida, the total area is probably more than 2,000 acres. The Florida Experiment Station has never approved and released this grass. Unauthorized acquisitions were made by some individuals who increased and sold the rhizomes to farmers and ranchers. The most extensive plantings known to the writer are near DeFuniak Springs and Ocala. Very little spread by seed has been observed in Florida.

Some cattlemen producing cogon grass regard it a desirable forage crop due to considerable growth in winter and ability to produce good yields of forage on poor soils. It is generally regarded as inferior to other forage crops available to farmers.

Torpedo grass, originally from the Mediterranean area, is naturalized locally along the Atlantic and Gulf Coasts from Georgia to Louisiana. It was presumably introduced in ballast used by sailing vessels of the lumber trade. When established in rich moist spots, it can extend a heavy growth on nearby poor sandy areas. This characteristic led to trials as a forage plant on deep sandy soils prior to 1920. It did poorly on such sites but succeeded well on rich moist

lands. Some plantings were made in the Kissimmee River valley of Florida and later in other parts of Florida.

Torpedo grass is a good forage plant on rich soils and potentially a dangerous weed for cultivated land. Its rhizomes are heavier than those of cogon grass and mechanical control more difficult.

The area planted to torpedo grass is almost entirely in Florida. A few small plantings have been made in other states mainly for stabilization of highway shoulders and difficult drainage outlets. Probably torpedo grass is now established on more than five thousand acres in the southeastern United States.

This note is offered with the hope of encouraging weed control specialists to try various herbicides on cogon and torpedo grasses for both control and extermination in the southeastern United States.

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Prepared By

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This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Division of Weed Investigations does not assume responsibility for the subject matter cited.

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